THREE ESSAYS ON THE ECONOMICS OF REGULATION

BY

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THREE ESSAYS ON THE ECONOMICS OF REGULATION

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The objective in each essay is to model the strategic behavior of the "players" so as to capture the structure of existing regulatory institutions and yet produce tractable results. The unifying theme throughout is a revealing comparison between a given theoretical construct and its real world counterpart.

A substantial body of recent research finds that price-cap regulation is superior to cost-based regulation in that many of the distortions associated with the latter are reduced or eliminated entirely. In the first essay, we prove that the hybrid application of cost-based and price-cap regulation that characterizes current regulatory practice in the U.S. telecommunications industry may generate qualitative distortions greater in magnitude than those realized under cost-based regulation. The analysis further reveals that the firm subject to this modified form of price-cap regulation may have incentives to engage in waste and overdiversify in the noncore market.

The incentive regulation literature has focused on how to discipline the regulated firm. In the second essay, we consider how price-cap regulation might enable the firm to discipline the regulator. We show that under quite general conditions, the firm will prefer profit-sharing to pure

price-cap regulation under which it retains one hundred percent of its profits. Profit-sharing limits the incentives of regulators to take actions adverse to the firm's financial interests. The discipline imposed on the regulator results in a more profitable regulatory environment for the firm.

Public utilities are generally subject to a carrier of last resort (COLR) obligation which requires them to stand by with capacity in place to serve on demand. In our third essay, we find that when the competitive fringe is relatively reliable, imposing a COLR obligation (asymmetrically) on the incumbent firm will lower the optimal price. The optimal price is further reduced when the fringe chooses its reliability strategically. A principal finding is that the fringe may overcapitalize (undercapitalize) in the provision of reliability when the incumbent's COLR obligation is sufficiently low (high).

CHAPTER 1
GENERAL INTRODUCTION

Public utility regulation in the United States and Europe is being transformed by a number of market and institutional changes. Prominent among these are emerging competition and experimentation with alternatives to rate-of-return (ROR) regulation. These are not unrelated events and developing an understanding of the critical interaction between them is of paramount importance. Economic analysis is complex in such a dynamic environment because it is necessary to model the strategic behavior of the "players in the game" in a manner that captures the semblance of existing regulatory institutions yet still yields tractable results. This is the primary challenge that confronts us here.

Each of the three essays that comprise the core of this dissertation begins with a given theoretical model and then proceeds to build institutional realism into the mathematical structure. This modeling approach allows for a revealing comparison between the given theoretical model and its "real world" counterpart. The results of the analysis allow us to question, and in many cases reverse, a number of principal findings in the literature. These results should prove useful to researchers and policymakers in regulated industries.

Public utilities in the United States and Europe have traditionally been subject to ROR or cost-based (CB) regulation.[1] Under this form of regulation, the utility is allowed to earn a specified return on invested capital and recover all prudently incurred expenses. The efficiency

[1] We use these terms interchangeably throughout the analysis.

distortions under ROR regulation are well known and have been explored at length in the literature.

Price-cap (PC) regulation, under which the firm's prices rather than its earnings are capped, has recently attracted considerable attention by regulated firms, public utility regulators and the academic community. Following a successful trial of PC regulation with British Telecom, the Federal Communications Commission (FCC) adopted this new form of incentive regulation for AT&T and subsequently for the Regional Bell Operating Companies.

A substantial body of recent research examines the superiority of PC over CB regulation. One of the principal findings of this research is that PC regulation eliminates many of the economic distortions associated with CB regulation. Specifically, under CB regulation, the firm's tendency is to (i) underdiversify in the noncore (diversification) market, (ii) produce with an inefficient technology, (iii) choose suboptimal levels of cost reducing innovation, (iv) price below marginal cost in competitive markets under some conditions, and (v) misreport costs.

In the first essay titled *Superior Regulatory Regimes in Theory and Practice*, we examine whether the superiority of PC regulation endures once we depart from the strict provisions of the theoretical construct. We prove that although PC regulation is superior to CB regulation, it is not true that a movement from CB regulation in the direction of PC regulation is necessarily superior to CB regulation.

The type of hybrid application of CB and PC regulation that prevails currently in the telecommunications industry may generate qualitative distortions greater in magnitude than those realized under CB regulation. Moreover, we find that the firm operating under what we henceforth refer to as modified price-cap (MPC) regulation has incentives to engage in pure waste and overdiversify in the noncore market under some conditions. These are qualitative distortions

that do not arise under pure PC regulation.[2] The economic and public policy implications of these findings are disconcerting. While regulators initially adopted PC regulation in large measure to reduce the inefficiencies inherent in CB regulation, in practice these distortions may well be exacerbated.

The second essay is titled *Why Less May Be More Under Price-Cap Regulation*. In this essay, we examine incentive regulation from a different viewpoint, examining how the firm can discipline the regulator by choosing a particular form of PC regulation that aligns the regulator's interests with those of the firm.

We begin by recognizing that the firm may be able to reverse the standard principal-agent relationship by providing the regulator with a vested interest in its financial performance. By adopting a form of PC regulation that entails sharing profits with consumers, the firm can exploit the political control that consumers exercise over the regulator and thereby induce the regulator to choose a higher price or a lower level of competitive entry. Our major result shows that if demand is relatively price-inelastic and the regulator's weight on consumer surplus is not too large, the firm's profits will be higher under sharing than under pure price-caps. Sharing is thus a dominant strategy for the firm, so that less really is more.

In practice there is an important, albeit largely unrecognized, distinction between the regulator's commitment to a price-cap and the regulator's commitment to a specified market price. As long as the regulator controls the terms of competitive entry, market price is decreasing with entry, and such entry cannot be contracted upon, the regulator's commitment to a specified price-cap may be meaningless. This is a classic example of incomplete contracting. The regulator must

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[2] Under pure PC regulation, there is no profit-sharing with regulators (consumers). The firm retains one hundred percent of its profits.

be given the requisite incentives to limit competitive entry, but such incentives are absent under pure PC regulation.

The reason that pure PC regulation is problematic when competitive entry cannot be contracted upon is that the regulator incurs no cost by adopting procompetitive entry policies since it does not share in the firm's profits. Under pure PC regulation, the regulator is perfectly insulated from the adverse consequences of procompetitive entry policies. Under a profit-sharing scheme, the regulator can adopt procompetitive entry policies only at a cost of forgone shared profits. Consequently, the regulator will generally be induced to adopt a less aggressive competitive entry policy under PC regulation with sharing than under pure PC regulation. This is the manner in which sharing rules can discipline the actions of the regulator.

What may be surprising is that regulated firms are generally opposed to profit-sharing in practice, perhaps because it is believed that the sharing rule affects only the distribution of profits, but not their absolute level. The irony here is that the regulated firm may object to sharing on the grounds that it subverts economic efficiency, a result consistent with our first essay, only to discover that sharing leads to higher realized profits. We should therefore naturally expect the regulator to support pure PC regulation and the firm to support profit-sharing, yet we observe quite the opposite.

The third and final essay in this dissertation is titled *Designing Carrier of Last Resort Obligations*. The COLR obligation essentially charges the incumbent firm with responsibility for standing by with facilities in place to serve consumers on demand. The historical origins of the obligation are significant because it is the asymmetry of this obligation that is the source of the market distortion.

A public utility with a franchised right to serve a certificated geographic area maintains a responsibility to serve all consumers on demand. Yet, at least historically, there was a

corresponding obligation on the part of consumers to be served by the public utility. This balance evolved over time as a fundamental tenet of the regulatory compact. Regulators have been reluctant to relieve the incumbent of its COLR obligation when challenged by a fringe competitor over concern that consumers could be abandoned without access to essential services.

We find that the presence of a competitive fringe tends to place downward pressure on the optimal price set by the regulator. When the competitive fringe is relatively reliable, the imposition of an asymmetric COLR obligation on the incumbent firm will tend to reduce further the optimal price. Moreover when the fringe is allowed to choose its reliability strategically, the optimal price is lower yet. These results may support a regulatory policy of greater downward pricing flexibility for a market incumbent facing a fringe competitor while bearing an asymmetric COLR obligation.

Our principal finding is that the competitive fringe has incentives to overcapitalize (undercapitalize) in the provision of reliability when the COLR obligation is sufficiently low (high). Here, supply creates its own demand in that the need for a COLR may be validated as a self-fulfilling prophecy in equilibrium. Moreover, any attempt by the competitive fringe to exploit the COLR obligation by increasing reliability and stranding the incumbent's plant with the intent of raising its rivals' costs will prove self-defeating. These findings may help explain competitive fringe strategy in the telecommunications industry.

CHAPTER 2
SUPERIOR REGULATORY REGIMES IN THEORY AND PRACTICE

Introduction

A substantial body of recent research examines the superiority of price-based or price-cap (PC) over cost-based (CB) regulation.[1] One of the principal findings of this research is that PC regulation eliminates many of the economic distortions associated with CB regulation. Specifically, under CB regulation, the firm's tendency is to (i) underdiversify in the noncore (diversification) market; (ii) produce with an inefficient technology; (iii) choose suboptimal levels of cost reducing innovation; (iv) price below marginal cost in competitive markets under some conditions; and (v) misreport costs.

The objectives of this essay are twofold. First, we prove that although PC regulation is superior to CB regulation, it is not true that a movement from CB regulation in the direction of PC regulation is necessarily superior to CB regulation. The type of hybrid application of CB and PC regulation that prevails currently in the telecommunications industry may generate qualitative distortions greater in magnitude than those realized under CB regulation. Second, we prove that the firm operating under what we henceforth refer to as modified price-cap (MPC) regulation has incentives to engage in pure waste and overdiversify in the noncore market under some conditions. These are qualitative distortions that do not arise under price-cap regulation.

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[1] See for example Braeutigam and Panzar (1989), Brennan (1989), Vogelsang (1988) and Federal Communications Commission (1988). We shall use the terms price-based and price-cap regulation interchangeably. The latter term has come into vogue in the telecommunications industry due to recent experiments with capping prices by British Telecom and the Federal Communications Commission. See Beesley and Littlechild (1989).

The economic and public policy implications of these findings are disconcerting. While regulators initially adopted PC regulation in large measure to reduce the inefficiencies inherent in CB regulation, in practice it may actually serve to exacerbate these distortions.

The format for the remainder of this essay is as follows. The three regulatory regimes are defined in the second section. The third section provides a formal characterization of the MPC regulation model. The fourth section examines the efficiency properties of MPC regulation in comparison with CB and PC regulation. The main result is that social welfare can be lower under MPC regulation than under CB regulation. In the fifth section, we show that the regulated firm may engage in waste when there is a nonzero probability that the regulator will recontract and subject the firm to more stringent regulation. The sixth section is a conclusion and an assessment of the importance of these results for economic and public policy analysis in regulated industries. The Appendix provides an example in which waste is profitable for the firm.

Definitions of Regulatory Regimes

There are two markets, a core (regulated) market in which the firm is a monopolist and a noncore (competitive) market in which the firm is a price-taker.[2] It is useful to begin the formal analysis with a precise definition of each of the three regulatory regimes: CB, PC and MPC.

Cost-Based (CB) Regulation

Under CB regulation, the firm chooses output in the core and noncore markets subject to the constraint that core market revenues be no greater than the sum of core market attributable costs plus shared costs that have been allocated to the core market (i.e., core market zero profit constraint). As Braeutigam and Panzar (1989, p. 374) note, CB regulation combines elements of

[2] In the telecommunications industry, basic telephone access is an example of a core service, and voice messaging is an example of a noncore service.

rate-of-return regulation with fully distributed cost pricing. CB regulation serves as the benchmark regulatory regime for this analysis.

Price-Cap (PC) Regulation

Under PC regulation, the regulator sets a price-cap ($\bar{p}$) in the regulated core market. The firm is allowed to retain one hundred percent of the profits it generates subject only to the core market price-cap constraint. Because the firm retains all of its profits under this regime (i.e., there is no sharing of profits with ratepayers), the need for fully distributed costing (FDC) is obviated. That is, since there is no need for the regulator to differentiate between core and noncore profits, FDC is not required to allocate costs common to both core and noncore services. As will be shown subsequently, it is this characteristic of PC regulation that underlies its claim of superiority.

Modified Price-Cap (MPC) Regulation

Under MPC regulation the regulator again sets a price-cap ($\bar{p}$) in the regulated core market. Here, however, the firm is only allowed to retain a specified share of the profits it generates in the core market under the price-cap constraint. In practice, the firm's share of profits is generally decreasing with the level of core market profits.

The asset base of the local telephone companies is partitioned into core and noncore (or diversified) categories. In practice, this partition is based upon FDC. Hence, unlike the pure price-cap model examined by Braeutigam and Panzar (1989), price-cap regulation with sharing mechanisms must of necessity incorporate cost allocations. Notice that CB and MPC regulation thus share a common source of economic distortion.[3] In this sense, MPC regulation is a hybrid of CB and PC regulation.

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[3] Under MPC regulation, however, it is not the cost allocator per se that is the source of the distortion, but the interaction of the cost allocator with the regulatory tax function.

A Formal Characterization of MPC Regulation

The firm's problem [FP] is to maximize the sum of core and noncore profit through choice of outputs, subject to a price-cap constraint. Output is denoted by y_i, price by p_i, and attributable cost by $c^i(y_i)$, $i = 1,2$, where market 1 is the core market and market 2 is the noncore market. Revenues in the core market are denoted by $R^1(y_1)$. Shared costs are denoted by F. The firm's cost function is

(0) $$C(y_1,y_2) = F + c^1(y_1) + c^2(y_2).$$

Shared costs are allocated between the core and the noncore market by a cost allocator, $f(y_1,y_2) \in [0,1]$, that represents the fraction of shared costs allocated to the core market.[4] The allocator is increasing in core output and decreasing in noncore output. Hence, $f_1 > 0$ and $f_2 < 0$, where the subscripts denote partial derivatives. The relative output cost allocator is defined formally by $f(y_1,y_2) = y_1/(y_1 + y_2)$. The firm is a price-taker in the noncore market with the equilibrium parametric price in the noncore market given by p_e^*. Marginal cost in the noncore market is assumed to be increasing in output, $c_{22}^2 > 0$. We define social welfare by

(1) $$W(y_1,y_2) = \int_0^{y_1} p^1(\xi)d\xi + p_e^* y_2 - C(y_1,y_2) + S,$$

where $p^1(.)$ is the inverse demand function in the core market and S is consumer surplus in the noncore market which is a constant because price is parametric. Let $W^{MPC}(y_1,y_2)$ and $W^{CB}(y_1,y_2)$ represent social welfare under MPC and CB regulation, respectively. We further define CB regulation to be welfare-superior (inferior) to MPC regulation whenever $W^{MPC}(y_1,y_2) < (>)$ $W^{CB}(y_1,y_2)$.

The most common form of PC regulation in the telecommunications industry calls for core market profits to be taxed, or shared between the firm and its ratepayers. Define core market

[4] See Braeutigam (1980) for a discussion of cost allocators commonly used in regulated industries and their properties.

profits by $\pi_1 = R^1(y_1) - f(y_1,y_2)F - c^1(y_1)$. Let $T(\pi_1) \in [0,1]$ denote a regulatory tax function, where $1-T(\pi_1)$ is the share of each additional dollar in core market profits retained by the firm. In most state jurisdictions today, $T(\pi_1)$ is an increasing function, so $T'(\pi_1) > 0$. Depending on the jurisdiction, the regulatory tax function may be either concave or convex. Moreover, the majority of these MPC plans employ a ceiling, either explicitly or implicitly, on core market profits ($\bar{\pi}_1$) so that $T(\pi_1) = 1, \forall\ \pi_1 \geq \bar{\pi}_1$. Finally, except where otherwise noted it will prove expeditious to work with a constant regulatory tax function, $\bar{T}$, i.e., $T(\pi_1) = \bar{T}$.

Distortions Under MPC Regulation

In this section, we characterize the efficiency properties of the MPC model with a set of formal propositions.

Proposition 1: If $\bar{T} > 0$ the regulated firm under MPC regulation will supply inefficiently small output levels in the noncore market (i.e., $p_e^* > c_2^2$).[5]

Proof: The Lagrangian for the MPC model is given by

(2) $$\mathcal{L} = [1-\bar{T}(\pi_1)][R^1(y_1) - f(y_1,y_2)F - c^1(y_1)] + p_e^* y_2 - [1-f(y_1,y_2)]F - c^2(y_2) + \delta[y_1 - y_1^*].$$[6,7]

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[5] As Braeutigam and Panzar (1989) note, a similar result was proven by Sweeney (1982) in a somewhat different context.

[6] Since there is no demand uncertainty in this model, we can represent the price-cap constraint, $p_1 \leq p_1^*$, in terms of restrictions on output levels, $y_1 \geq y_1^*$, where y_1^* is the core market output level corresponding to a price of p_1^*.

[7] For ease of comparison, we provide a sketch of the Braeutigam and Panzar (1989, p. 380) proof for the CB regulation model. The Lagrangian is given by
(1.1) $H = R^1(y_1) + p_c^* y_2 - F - c^1(y_1) - c^2(y_2) + \lambda[f(y_1,y_2)F + c^1(y_1) - R^1(y_1)]$,
where λ is the Lagrange multiplier on the core market zero-profit constraint. Differentiating (1.1) with respect to y_2, assuming an interior solution and rearranging terms, we obtain
(1.2) $p_c^* - c_2^2 = -\lambda F f_2 > 0$,
since $\lambda > 0$ when the zero-profit constaint binds and $f_2 > 0$.

The first-order condition for noncore output, y_2, assuming an interior solution and a constant regulatory tax function is given by:

$$(3) \qquad \partial\mathcal{L}/\partial y_2 = -(1-\bar{T})f_2F + p_e^* + f_2F - c_2^2 = 0.$$

Rearranging terms and simplifying yields

$$(4) \qquad p_e^* - c_2^2 = -f_2F\bar{T} > 0.^{8,9} \quad \blacksquare$$

The underproduction distortion occurs under MPC regulation because each additional unit of noncore output imposes two costs on the regulated firm. First, there is the marginal cost that is directly attributable to producing the noncore service, c_2^2. In addition, shared costs are shifted from the core to the noncore market at the rate of f_2F. As a result, the firm gains $(1-\bar{T})$ in increased profits in the core market yet realizes -1 in increased costs in the noncore market. The

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[8] Relaxing the assumption of a constant regulatory tax function leads to a further output distortion in the same direction. It can be shown that the equilibrium condition for this more general formulation is given by the following expression: $p_e^* - c_2^2 = -f_2F[\bar{T} + \pi_1\bar{T}'] > 0$. Increasing noncore market output now has two separate effects: (1) common costs shift from the core to the noncore market, which raises profits in the core market by $1-\bar{T}$ and reduces profits in the noncore market by -1 for a net effect of $-\bar{T}$; (2) the increased level of profits in the core market raises the effective regulatory tax, which reduces the level of core profits retained by $\pi_1\bar{T}'$.

[9] Similar results hold when there is a nonzero probability that the regulator will disavow the price-cap commitment and force the firm to recontract. Let $\phi(\pi_1)$ and $1-\phi(\pi_1)$ define the firm's subjective probability that the regulator will recontract (i.e., honor the price-cap commitment) and not recontract, respectively. If the regulator does recontract, the firm is assumed to face a core market profits tax of $\bar{T} > 0$. A natural assumption is that the higher the reported core market profits, the higher the probability that the regulator will recontract, hence, $\phi'(\pi_1) > 0$. In this case, $p_e^* - c_2^2 = -f_2F[\phi\bar{T} + \phi'\bar{T}\pi_1] > 0$. There are once again two separate effects associated with increasing output in the noncore market: (1) common costs shift from the core to the noncore market, raising profits by $1-\phi\bar{T}$ in the core market and reducing profits in the noncore market by -1 for a net effect of $-\phi\bar{T}$; (2) increased profits in the core market raise the probability that the regulator will force the firm to recontract. The expected change in core market profits for the firm is thus $-\phi'\bar{T}\pi_1$. This result provides some intuition for the distortions induced by commitment uncertainty. See Weisman (1989a, p. 165 and notes 30 and 31) for a discussion of the intergenerational distortions resulting from a nonzero probability of recontracting.

net effect is negative $\forall\ \bar{T} > 0$. The magnitude of this distortion is monotonically increasing in $\bar{T}$.[10]

Now consider the diversification distortion that arises under MPC regulation in the presence of vertically integrated markets. As the earnings ceiling is approached so $\bar{T} \rightarrow 1$, the firm operating in vertically integrated markets may overdiversify, i.e., it may choose an output level at which marginal cost exceeds the parametric price. This occurs because the high tax rate in combination with the vertical market relationship reduces the firm's effective input cost for noncore production. The firm responds by increasing output in the noncore market.

Some additional notation is required for making this point formally. Let z_1 denote units of y_1 used exclusively as inputs in the production of y_2. Hence, we can write $z_1 = h(y_2)$. The revenue derived from the sale of z_1 is denoted by $R^1(z_1)$.

This set-up conforms with the institutional structure of the telecommunications industry, where y_1 denotes retail local calls, y_2 denotes retail long-distance calls, and z_1 represents wholesale local calls used exclusively as inputs to complete the local connections (access) of long-distance calls. Hence, the demand for z_1 is a derived demand from y_2.

Definition 1: The input z_1 is an essential input in the production of y_2 if y_2 cannot be produced without z_1, or y_2 can be produced without z_1 but only at a cost that would make such production unremunerative.

Proposition 2: Suppose that z_1 is an essential input in the production of y_2. Then for $\bar{T}$ sufficiently close to unity, the firm operating under MPC regulation will overdiversify if $(dz_1/dy_2) > -f_2/f_1$.

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[10] The distortion under MPC regulation can be greater than (less than) the distortion under CB regulation. See proposition 3 and the discussion of social welfare.

Proof: The Lagrangian for the MPC regime is given by:

(5) $$\mathcal{L} = [1-\bar{T}(\pi_1)][R^1(y_1) + R^1(z_1) - f(y_1 + z_1,y_2)F - c^1(y_1 + z_1)] + p_e^* y_2$$

$$- [1-f(y_1 + z_1,y_2)]F- c^2(y_2) + \delta[(y_1 + z_1) - (y_1 + z_1)^*].$$[11]

Assuming the price-cap constraint does not bind, the first-order condition for y_2 is given by

(6) $$\partial\mathcal{L}/\partial y_2 = (1-\bar{T})[(\partial R^1/\partial z_1 - f_1F-c_1^1)(dz_1/dy_2)-f_2F] + p_e^* + f_1F(dz_1/dy_2)$$

$$+ f_2F - c_2^2 = 0.$$

Rearranging terms, we obtain

(7) $$p_e^* - c_2^2 = -(1-\bar{T})[(\partial R^1/\partial y_1 - f_1F-c_1^1)(dz_1/dy_2)-f_2F] -f_1F(dz_1/dy_2) -f_2F.$$

Further rearranging of terms yields

(8) $$p_e^* - c_2^2 = -F\bar{T}[f_1(dz_1/dy_2) + f_2]-(1-\bar{T})\{(\partial R^1/\partial z_1-c_1^1)(dz_1/dy_2)\}.$$

Assuming marginal revenue for z_1 is bounded, then for $\bar{T}$ sufficiently close to unity, equation (8) reduces to

(9) $$p_e^* - c_2^2 = -F[f_1(dz_1/dy_2)+ f_2].$$[12]

Since z_1 is an input in the production of y_2, $dz_1/dy_2 > 0$. The term inside the brackets in (8) is thus positive whenever $(dz_1/dy_2) > -f_2/f_1$. Thus, when this condition holds, $p_e^* < c_2^2$. ■

[11] Note that we have assumed here that z_1 and y_1 have the identical cost structure and cost allocator. This facilitates computational ease and yet does not fundamentally alter the general result.

[12] It is straightforward to show that with a binding price-cap constraint the equivalent condition is given by $p_e^* - c_2^2 = -F\bar{T}[f_1(dz_1/dy_2) + f_2] + \delta(dp_1/dz_1)(dz_1/dy_2)$. Since $\delta \geq 0$ and $dp_1/dz_1 < 0$, none of the qualitative results are affected by the assumption that the price-cap constraint is nonbinding.

Hence, when the vertical relationship is sufficiently strong (dz_1/dy_2 is sufficiently large), the firm will overdiversify in that it will choose a level of output in the noncore market at which marginal cost exceeds the parametric price.

Corollary to Proposition 2: For the relative output cost allocator, the firm will overdiversify in the noncore market if $\bar{T}$ is sufficiently close to unity and $dz_1/dy_2 > (y_1 + z_1)/y_2$.

Proof: For the relative output cost allocator,

(10) $f_1 + f_2 = (y_2 - y_1 - z_1)/(y_1 + z_1 + y_2)^2$.

Hence, from proposition 2, the corollary will hold if

(11) $[y_2(dz_1/dy_2) - y_1 - z_1]/(y_1 + z_1 + y_2)^2 > 0$,

or

(12) $dz_1/dy_2 > (y_1 + z_1)/y_2$,

which is satisfied for dz_1/dy_2 and/or y_2, sufficiently large. ■

Hence, if the vertical relationship is sufficiently strong and/or the noncore market is sufficiently large, the firm will overdiversify in the noncore market.

The intuition for these results is as follows. Each additional unit of output in the noncore market generates increased demand for the intermediate good, z_1. When output increases in the core market, shared costs are shifted from the noncore to the core market which the firm views as a de facto subsidy to noncore production. This leads the firm to choose a level of production in the noncore market greater than that which is chosen in the absence of a vertical relationship.

To illustrate, consider the case of access (z_1) and long-distance telephone service (y_2). Each long-distance telephone call requires two local access connections, one each at the origination and termination points of the call. This production relation implies that $dz_1/dy_2 = 2$. Hence, a sufficient condition for the vertically integrated firm to overdiversify in the long-distance

telephone market is that the firm's output in the long-distance market be greater than one half that of the firm's output in the combined local and access telephone service market, or $y_2 > (y_1 + z_1)/2$.

Social Welfare Results

The above propositions examine various qualitative distortions under MPC regulation. In this subsection, we compare social welfare under MPC and CB regulation. The propositions identify an important nonconvexity whereby a move in the direction of pure PC regulation may actually reduce welfare. We begin by proving a number of useful lemmas.

Lemma 1: If $\bar{T} = \lambda$ (the Lagrange multiplier on the zero-profit constraint in the CB model)[13] and $\delta = 0$ at the solution to [FP], then the core and noncore output levels are the same under CB and MPC regulatory regimes.

Proof: This result follows immediately from examination of the relevant first-order conditions. ■

Lemma 2: If $\delta > 0$, then $dy_1/d\bar{T} = 0$ and $dy_2/d\bar{T} < 0$ at the solution to [FP] under MPC regulation.

Proof: The Lagrangian for [FP] under MPC regulation is

(13) $$\mathcal{L} = [1-\bar{T}(\pi_1)][R^1(y_1) - f(y_1,y_2)F - c^1(y_1)] + p_e^* y_2 - [1-f(y_1,y_2)]F - c^2(y_2) + \delta[y_1 - y_1^*].$$

The necessary first-order conditions for an interior optimum include

(14) $$[1-\bar{T}][R_1^1(y_1) - f_1F - c_1^1] + f_1F + \delta = 0,$$

(15) $$[1-\bar{T}][-f_2F] + p_e^* + f_2F - c_2^2 = 0, \text{ and}$$

[13] Braeutigam and Panzar (1989, p. 378) prove that $\lambda \in (0,1)$ in the CB regulation model so that it is always possible to choose $\bar{T}$ equal to λ. See also note 7 above.

(16) $\quad y_1 - y_1^* = 0.$

Rearranging terms and differentiating the first-order conditions with respect to the tax rate, $\bar{T}$, we obtain

(17) $\quad \Big[\{1-\bar{T}\}[R_{11}^1(y_1)-f_{11}F-c_{11}^1]+f_{11}F] \Big] dy_1/d\bar{T}+\bar{T}f_{12}dy_2/d\bar{T}+d\delta/d\bar{T}=R_1^1(y_1)-f_1F-c_1^1,$

(18) $\quad \bar{T}f_{21}Fdy_1/d\bar{T} + \{\bar{T}f_{22}F - c_{22}^2\}dy_2/d\bar{T} = -f_2F,$ and

(19) $\quad dy_1/d\bar{T} = 0.$

From Cramer's rule,

(20) $$dy_1/d\bar{T} = \frac{\begin{vmatrix} R_1^1(y_1)-f_1F-c_1^1 & \bar{T}f_{12} & 1 \\ -f_2F & \bar{T}f_{22}F - c_{22}^2 & 0 \\ 0 & 0 & 0 \end{vmatrix}}{|H|}$$

where H is the relevant bordered Hessian. |H| must be positive at a maximum. Expanding the determinant in (20), we obtain

(21) $\quad dy_1/d\bar{T} = 0.$

Similarly for $dy_2/d\bar{T}$,

(22) $$dy_2/d\bar{T} = \frac{\begin{vmatrix} [1-\bar{T}]R_{11}^1(y_1)-f_{11}F-c_{11}^1]+f_{11}F & R_1^1(y_1)-f_1F-c_1^1 & 1 \\ \bar{T}f_{21}F & -f_2F & 0 \\ 1 & 0 & 0 \end{vmatrix}}{|H|}.$$

Expanding the determinant in (22), we obtain

(23) $\quad dy_2/d\bar{T} = f_2F < 0.$ ■

In the next proposition, we prove that CB regulation can be welfare superior to MPC regulation if social welfare is initially equal under the two regimes and the price-cap (output) constraint binds.

Proposition 3: If $W^{MPC} = W^{CB}$ and $\delta > 0$ in the solution to [FP], then for a small increase in $\bar{T}$, $W^{MPC} < W^{CB}$.

Proof: The change in social welfare, for dy_1 and dy_2 small, is given by

(24) $dW = (p_1 - c_1^1)dy_1 + (p_e^* - c_2^2)dy_2.$

By lemma 2, $dy_1/d\bar{T} = 0$ and $dy_2/d\bar{T} < 0$, so that

(25) $dW/d\bar{T} = (p_e^* - c_2^2)dy_2 < 0,$

since $p_e^* > c_2^2$ by proposition 1. ■

In the telecommunications industry, it is common practice for regulators to freeze the basic monthly service charge at current levels so that the price under CB regulation serves as the price-cap under MPC regulation. In the following corollary, we explore the effect of an increase in the tax rate, $\bar{T}$, when the firm holds the core market output level constant, an assumption not inconsistent with institutional reality.

Corollary to Proposition 3: If $W^{MPC} = W^{CB}$, $\delta = 0$ and core market output is constant, then for a small increase in $\bar{T}$, $W^{MPC} < W^{CB}$.

Proof: Differentiating equation (17), which implicitly defines y_2^*, with respect to $\bar{T}$, we obtain

(26) $[1-\bar{T}][-f_{22}F][dy_2/d\bar{T}] + f_{22}F[dy_2/d\bar{T}] - c_{22}^2[dy_2/d\bar{T}] = -f_2F.$

Collecting terms and simplifying yields

(27) $dy_2/d\bar{T} = -f_2F/[\bar{T}f_{22}-c_{22}^2] < 0,$

since $f_2 < 0$ and the denominator is negative by a necessary second order condition for a maximum. The result follows directly from proposition 1. ■

The firm chooses output levels in the core and noncore markets to maximize total profits. These optimal output levels jointly define an equilibrium allocation of shared costs between the core and the noncore markets. An increase in the tax rate, $\Delta\bar{T} > 0$, with core market output unchanged, perturbs the equilibrium allocation of shared costs as it now becomes more profitable

for the firm to recover a larger proportion of shared costs in the core market. To see this, recognize that the cost to the firm for each dollar of shared costs allocated to the core market falls from $[1-\bar{T}]$ to $[1-(\bar{T}+\Delta\bar{T})]$. The firm responds by shifting additional shared costs to the core market. With core market output unchanged, the only way the firm can shift shared costs to the core market is by reducing output in the noncore market. Core market output is thus the same as under CB regulation but noncore output is lower. It follows that social welfare can be lower under MPC regulation than under CB regulation.

Welfare-Superiority Example

We now turn to a specific example to provide some intuitive appreciation for these results. Let the firm's inverse demand function be given by $p^1(y_1) = 20 - y_1$, where core market revenues are $R^1(y_1) = 20y_1 - y_1^2$. The parametric price in the noncore market is $p_e^* = 5$. The firm's cost function is $C(y_1, y_2) = 92 + y_1 + 0.5y_2^2$. We employ a relative cost allocator of the form $f(y_1, y_2) = y_1/(y_1 + y_2)$, where $f_1 = y_2/(y_1 + y_2)^2$ and $f_2 = -y_1/(y_1 + y_2)^2$. Setting the firm's break-even profit level at 10, the Lagrangian for the [FP] under the CB regulatory regime is given by

(28) $\mathcal{L} = 19y_1 - y_1^2 + 5y_2 - 92 - 0.5y_2^2 + \lambda[10 + 92y_1/(y_1 + y_2) - 19y_1 + y_1^2]$.

The necessary first-order conditions for an interior optimum include

(29) y_1: $[19 - 2y_1][1-\lambda] + 92y_2\lambda/(y_1 + y_2)^2 = 0$,

(30) y_2: $5 - y_2 - 92y_1\lambda/(y_1 + y_2)^2 = 0$, and

(31) λ: $10 + 92y_1/(y_1 + y_2) - 19y_1 + y_1^2 = 0$.

Equations (29)-(31) represent three simultaneous nonlinear equations in three unknowns: y_1, y_2, and λ. Numerical simulation techniques reveal the following solution: $y_1 = 10.02913$, $y_2 = 1.50870$ and $\lambda = 0.503715$.

From lemma 1, we know that if $\bar{T} = 0.503715$ and $\delta = 0$, then the core and noncore output levels are the same under MPC and CB regulation. From equation (1), it can be shown that $W^{MPC} = W^{CB} = 54.67 + S$, where S is the constant level of consumer surplus in the noncore market. Now suppose that we allow for a marginal increase in the regulatory profits tax under MPC regulation from $\bar{T} = 0.503715$ to $\bar{T} = 0.521975$. It can be shown that the new level of welfare under MPC regulation is 45.26 + S, so that the change in welfare is -9.41. We have thus demonstrated by example that CB regulation can be welfare-superior to MPC regulation.

Recontracting Induced Distortions in the MPC Model

One of the more serious concerns with PC regulation in practice is the prospect that the firm will fare too well under this new regulatory regime and regulators will recontract, or subject the firm to more stringent regulation. Let $\phi(\pi_1)$ define the firm's subjective probability that the regulator will recontract, in which case the firm's core market profits are assumed to be taxed at the rate $\bar{T}$. If recontracting does not occur, the firm is assumed to retain all of its profits. We further define the recontracting elasticity as $\varepsilon_\phi = \phi'\pi_1/\phi$. In the next proposition, we show that conditions exist under which the firm has incentives to engage in pure waste under MPC regulation. Pure waste in this context refers to the purchase of costly inputs which have no productive value.

Proposition 4: The risk-neutral firm operating under MPC regulation will have incentives to engage in pure core waste whenever $\varepsilon_\phi > (1 - \phi\bar{T})/\phi\bar{T}$.

Proof: The Lagrangian with pure waste variables u_1, u_2, and u_F, respectively representing core, noncore and shared waste, is given by

$$(32) \qquad \mathcal{L} = [\phi(\pi_1)(1-\bar{T}) + (1-\phi(\pi_1))][R^1(y_1) - f(y_1, y_2)(F + u_F) - c^1(y_1) - u_1]$$

$$+ p_e^* y_2 - [1-f(y_1,y_2)](F + u_F) - c^2(y_2) - u_2 + \delta[y_1 - y_1^*].$$

Let aggregate profits be denoted by $\pi = \pi_1 + \pi_2$. By the Envelope Theorem, an increase in core market waste is profitable for the firm whenever

(33) $$d\pi/du_1 = [\partial\pi_1/\partial u_1]\left[\pi_1[\phi'(\pi_1)(1-\bar{T})-\phi'(\pi_1)] + [\phi(\pi_1)(1-\bar{T}) + 1-\phi(\pi_1)]\right] > 0.$$

Recognize that $[\partial\pi_1/\partial u_1] = -1$. Rearranging terms yields,

(34) $$\phi'\bar{T}\pi_1 + [\phi\bar{T} - 1] > 0,$$

(35) $$\phi'\bar{T}\pi_1 > 1 - \phi\bar{T},$$

(36) $$\phi'\bar{T}\pi_1/\phi\bar{T} > (1 - \phi\bar{T})/\phi\bar{T},$$

and, by the definition of the recontracting elasticity,

(37) $$\varepsilon_\phi > (1 - \phi\bar{T})/\phi\bar{T}.$$[14] ■

There are two separate effects on profits associated with the firm engaging in pure core waste. The first effect is positive and corresponds to the first term in equation (34). Each dollar of pure core waste reduces the probability that the regulator will recontract (i.e. levy a profits tax equal to $\bar{T}$) and thus enables the firm to retain a larger share of realized profits. The second effect is negative and corresponds to the second term in equation (34). Each dollar of pure core waste reduces the realized profits of the firm by precisely $1-\phi\bar{T}$.

In contrast to CB regulation, there exist conditions under which the firm will engage in pure core waste under MPC regulation.[15] Also note that since $d/d\bar{T}\{(1-\phi\bar{T})/\phi\bar{T}\} = -[\phi^2\bar{T} +$

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[14] In the more general case in which the firm is initially taxed at a rate of $\bar{T}_i$ and recontracting results in a tax of $\bar{T}_j$, where $\bar{T}_i < \bar{T}_j$, the core waste condition can be shown to be given by $\varepsilon_\phi > [1-\bar{T}_i - \phi(\bar{T}_j - \bar{T}_i)]/\phi(\bar{T}_j - \bar{T}_i)$. Note that when $\bar{T}_i = 0$, this expression reduces to $\varepsilon_\phi > 1 - \phi\bar{T}_j/\phi\bar{T}_j$, which corresponds to the standard MPC model examined in the proposition.

[15] Similar results hold when the firm faces a zero probability of recontracting, but the regulatory tax function is increasing in core market profits, π_1. In this case, it can be shown that the firm will engage in pure waste whenever $\varepsilon_T > (1-T)/T$, where $\varepsilon_T = T'(\pi_1)\pi_1/T$ is the elasticity of the tax function with respect to core market profits. The logic is similar to that outlined in the text.

$\phi(1-\phi\bar{T})]/(\phi\bar{T})^2 = -1/\phi\bar{T}^2 < 0$, the higher the profits tax, the lower the level of core market profits at which the firm will have incentives to engage in pure waste. Figure 2-1 illustrates the increasing divergence between retained and earned profits as core market profits increase. Eventually, a point is reached where core market profits retained are nonincreasing with respect to core market profits earned. The firm will have incentives to engage in pure waste for all core market profit levels beyond this point. The Appendix provides an example of this phenomenon.

It can easily be shown that the firm will engage in pure shared waste whenever $\boldsymbol{\varepsilon}_\phi >$ $(1-\phi f\bar{T})/\phi f\bar{T} > (1-\phi\bar{T})/\phi\bar{T}$. As might be expected, the conditions under which the firm has incentives to engage in pure shared waste are more restrictive than the conditions under which the firm will engage in pure core waste. Moreover, as with CB regulation, it is straightforward to show that the firm operating under MPC regulation will not engage in pure noncore waste, since this simply reduces aggregate profits.

Technology Distortions

In this subsection, we turn to the question of whether the firm will choose the efficient technology and retain incentives to misreport the nature of its costs under MPC regulation.

In the next proposition, we assume shared costs, F, reduce both core and noncore attributable costs. The efficient level of shared costs, F*, is obtained when the firm invests in shared costs up to the point where the last dollar invested in shared costs reduces the sum of core and noncore attributable costs by precisely one dollar. We define F* formally as follows.

Definition 2: $F^*(y_1, y_2) = \underset{F}{\text{argmin}}\{F + c_1(y_1,F) + c_2(y_2,F)\}$, where $\partial c_i/\partial F < 0$ and $\partial^2 c_i/\partial F^2 > 0$, i = 1,2.

Proposition 5: If $\bar{T} > 0$ and $f \neq -c^1_F$, the firm's choice of technology is inefficient under MPC regulation.

Proof: The Lagrangian is given by

(38) $$\mathcal{L} = [1-\bar{T}(\pi_1)][R^1(y_1) - f(y_1,y_2)F - c^1(y_1,F)] + p_e^* y_2 - [1-f(y_1,y_2)]F$$

$$- c^2(y_2,F) + \delta[y_1 - y_1^*].$$

The necessary first-order condition for an interior optimum is given by

(39) $$-(1-\bar{T})(f + c_F^1) - (1-f) - c_F^2 = 0.$$

Rearranging terms yields

(40) $$-c_F^1 - c_F^2 = 1 - \bar{T}(f + c_F^1), \text{ so generally } F(.) \neq F^*. \blacksquare$$

The efficient choice of F is induced only if $\bar{T}(\pi_1) = 0$, $\forall\ \pi_1$ (i.e., pure price-caps) or $f = -c_F^1$. Hence, in general, the firm's choice of technology is distorted. It is not difficult to show that the magnitude of the distortion can be greater under MPC regulation than under CB regulation.[16]

Cost Misreporting Distortions

Finally, one of the benefits of PC regulation is that the regulated firm has no incentive to misreport the nature of its costs (Braeutigam and Panzar, 1989, p. 388). In particular, it would not have an incentive to claim costs actually incurred in the noncore market were incurred in the core market. This is because under PC regulation prices are not raised to cover misreported costs, as they may be under CB regulation. It is straightforward to show that the firm retains its incentives to misreport costs under MPC regulation. We record this result in our final proposition.

Proposition 6: In decreasing order of profitability, the profit-maximizing firm under MPC regulation has incentives to report (i) noncore costs as core costs and (ii) noncore costs as shared costs.

[16] We, like Braeutigam and Panzar (1989), can ask whether the firm will invest efficiently in cost saving innovation under MPC regulation. In general, it will not. The proofs for MPC regulation are identical to Braeutigam and Panzar's for CB regulation, again with $\bar{T}$ replacing λ.

Proof: When core costs increase by 1, total profits fall by only $(1-\bar{T}) < 1$. When shared costs increase by 1, total profits fall by $(1-\bar{T})f + (1-f) = (1-\bar{T}f) < 1$. The result follows from the chain of inequalities $(1-\bar{T}) < (1-\bar{T}f) < 1$. ■

Conclusion

Although well-known distortions under CB regulation are either reduced or eliminated entirely under pure PC regulation, a move from CB regulation toward price-cap regulation may not improve upon CB regulation. This is an important finding for both theoretical and applied research, as currently these hybrid applications are the rule rather than the exception.

Under MPC regulation, the profit-maximizing firm has incentives to (i) underdiversify in the case of independent demands, (ii) overdiversify in the case of vertically integrated markets, (iii) use inefficient technologies, and (iv) misreport costs. Moreover, under MPC regulation, the firm may have incentives to engage in pure waste if it believes that higher profits may induce the regulator to recontract. This qualitative distortion does not arise under CB regulation.

This issue of recontracting and the attendant efficiency distortions resulting therefrom is arguably one of the more serious problems with PC regulation in practice. A key premise underlying PC regulation is that increased profits for the firm will be viewed by regulators and their constituency as something other than a failure of regulation itself. If this premise is false, then regulators will be under constant political pressure to recontract when the firm reports higher profits. In equilibrium, the firm learns that this is how the game is played and the efficiency gains from PC regulation in theory may fail to materialize in practice.

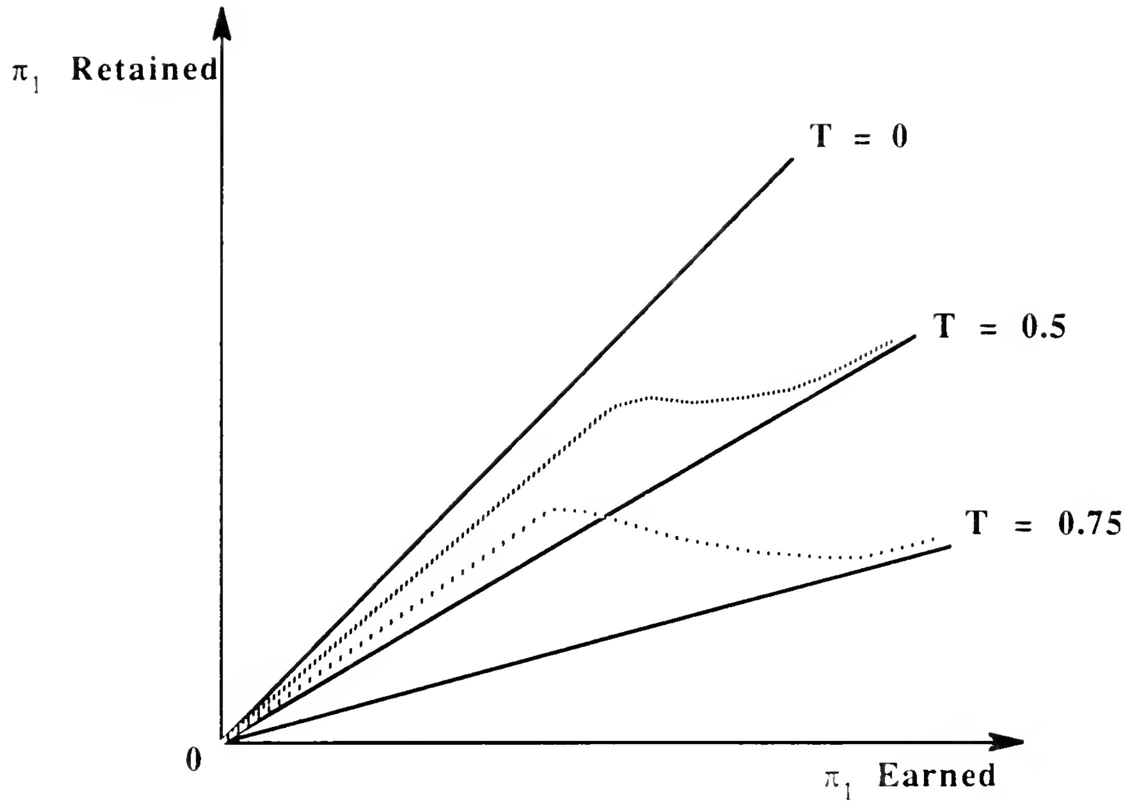

Figure 2-1: Waste Incentives with Increasing Probability of Recontracting.

CHAPTER 3
WHY LESS MAY BE MORE UNDER PRICE-CAP REGULATION

Introduction

Public utilities in the United States and Europe have traditionally been subject to rate-of-return (ROR) regulation. Under this form of regulation, the utility is allowed to earn a specified return on invested capital and recover all prudently incurred expenses. The efficiency distortions under ROR regulation are well known and have been analyzed at length in the literature.[1] Price-cap (PC) regulation, under which the firm's prices rather than its earnings are capped, has recently attracted considerable attention by regulated firms, public utility regulators and the academic community.[2] Following the perceived success of PC regulation in early trials involving British Telecom, the Federal Communications Commission (FCC) adopted this new form of incentive regulation for AT&T and subsequently for the Regional Bell Operating Companies.[3]

Most of the formal literature on incentive regulation has focused on the manner in which the firm is disciplined under a particular regulatory regime.[4] In this paper, we examine incentive

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[1] See Braeutigam and Panzar (1989) for a comprehensive treatment.

[2] *Rand Journal of Economics* (Autumn 1989) includes a special section on price-cap regulation. See, in particular, the articles by Beesley and Littlechild (1989) and Schmalensee (1989). See also Brennan (1989) and Cabral and Riordan (1989).

[3] See Federal Communications Commission (1988).

[4] See for example Baron (1989), Braeutigam and Panzar (1989), Brennan (1989), Cabral and Riordan (1989), Caillaud et al. (1988), Sappington and Stiglitz (1987) and Besanko and Sappington (1986).

regulation from a different viewpoint--examining how the firm can discipline the regulator by choosing a particular form of PC regulation that aligns the regulator's interests with those of the firm. By effectively reversing the standard principal-agent relationship, the firm may be able to induce the regulator to choose a higher price or a lower level of competitive entry by adopting a form of PC regulation that entails sharing profits with consumers. Our major result shows that if demand is relatively inelastic and the regulator's weight on consumer surplus is not too large, the firm's profits will be higher under sharing than under pure price-caps. Sharing is thus a dominant strategy for the firm, so that less really is more.[5]

In practice there is an important distinction between the regulator's commitment to a price-cap and the regulator's commitment to a specified market price. As long as the regulator controls the terms of competitive entry, market price is decreasing with entry and such entry cannot be contracted upon, the regulator's commitment to a specified price-cap may be meaningless.[6] This is a classic example of incomplete contracting. The regulator must be given the requisite incentives to limit competitive entry, but such incentives are absent under pure PC regulation.[7]

The reason that pure PC regulation is problematic when competitive entry cannot be contracted upon is that the regulator incurs no cost by adopting procompetitive entry policies since it does not share in the firm's profits. Under pure PC regulation, the regulator is in some sense

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[5] Schmalensee (1989) argues that in many cases, the welfare gains from sharing dominate those from pure price-caps. This occurs because under sharing, consumers directly benefit from the cost-reducing efforts of the firm, whereas the firm retains all of the benefits of these efforts under pure price-caps. This welfare argument is very different from the strategic argument offered here.

[6] The local telephone companies clearly did not believe that a price-cap commitment was meaningless, as they agreed to significant rate concessions and large-scale (unremunerative) network modernization in exchange for it.

[7] Under pure PC regulation, there is no profit-sharing with regulators (consumers).

fully insured against the adverse consequences of procompetitive entry policies. Under a profit-sharing scheme, the regulator can adopt procompetitive entry policies only at a cost of forgone shared profits. Consequently, the regulator will generally be induced to adopt a less aggressive competitive entry policy under PC regulation with sharing than under pure PC regulation. This is the manner in which sharing rules can discipline the actions of the regulator.

The primary objective of this essay is to show that under quite general conditions, sharing dominates pure PC regulation in that the firm's profits are higher when profits are shared than when they are retained by the firm in full. Sharing provides the regulator with a vested interest in the financial performance of the firm. This is illustrated in Figure 3-1. The firm is able to exert upstream control over the actions of the regulator by agreeing to share profits with consumers. It may thus be able to induce the regulator to choose a higher price or a lower level of competitive entry. What is surprising is that regulated firms are generally opposed to profit-sharing in practice, perhaps because it is believed that the sharing rule affects only the distribution of profits but not their absolute level. This sentiment is reflected in a recent filing by Southwestern Bell Telephone:

> Sharing of earnings is inappropriate for any regulatory reform proposal. Sharing bands and floors continue the disadvantages, for both customer and company, of rate base rate of return regulation. . . . Consequently, the basic economic principle of incentive regulation will be subverted if any form of revenue sharing is incorporated in an incentive regulation plan. . . . The principal operative force in business, whether it be competitive or regulated, is the quest for profits. (Southwestern Bell Telephone (1992), Question 18, page 1 of 1)

The irony here is that the regulated firm may object to sharing on grounds that it subverts economic efficiency, only to discover that sharing leads to higher realized profits.

The analysis proceeds as follows. The elements of the formal model are developed in the second section. The benchmark results are presented in the third section. In the fourth section, we present our principal findings. The conclusions are drawn in the fifth section.

Elements of the Model

The regulator's objective in this problem is to maximize a weighted average of consumer surplus and shared profits. Following the work of Posner (1971, 1974), the regulator is able to tax the profits of the firm and distribute these tax dollars to consumers. Let β denote the regulator's weight on consumer surplus, and $(1-\beta)$ is the corresponding weight on shared profits. The regulator's effective weight on shared profits is $(1-\alpha)(1-\beta)$, where $(1-\alpha)$ is the regulator's share of total accounting profits. Through its choice of α, the firm is able to influence the regulator's relative valuation of consumer surplus. It follows that when the firm chooses pure price-caps ($\alpha = 1$), the regulator's objective function is maximized by choosing the lowest price (highest level of competitive entry) consistent with the firm's willingness to participate. By choosing a value for α on the interval $[0,1)$, the firm provides the regulator with vested interest in its financial perfomance. Under conditions to be described, the firm is able to strategically exploit this vested interest and realize higher profits as a result.

There are two players in the game to be analyzed: the firm and the regulator. The firm's realized profits are denoted by $\pi^R = \pi^A - \psi(I)$, where $\pi^A \equiv q(p,e)p - c(q,\mu I)$ denotes the firm's accounting profits. I is the firm's (unobservable) effort level, and $\psi(I)$ is a monetary measure of the firm's disutility in expending effort. We maintain the standard assumptions that $\psi(I)$ is an increasing, convex function so that $\psi'(I) > 0$, $\psi''(I) > 0$ and $\psi(0) = 0$. We define p to be market price, e is the level of competitive entry allowed by the regulator,[8] Q(p) is market demand, q(p,e) is the firm's demand, where $q(p,0) = Q(p)$, $q_p < 0$ and $q_e \leq 0$.[9] The condition $q_e \leq 0$ is referred

[8] Entry (e) is modeled as a continuous variable because the terms of competitive entry are set by the regulator. For example, in the telecommunications industry, regulators set the rates that competitors pay to interconnect with the incumbent's network. Hence, low (high) interconnection charges may be interpreted as liberal (conservative) competitive entry policies.

[9] The subscripts denote partial derivatives.

to as the demand dissipation effect. Increased entry reduces the demand base for the regulated incumbent firm, ceteris paribus. The own price elasticity of demand is defined by $\varepsilon_p = -q_p(p/q)$. The firm's cost function is $C(q,\mu I) = c(q,\mu I) + \psi(\mu I)$, where $c_q > 0$, $c_I < 0$ and $c_{II} > 0$. We assume further that $c_I(q,I)|_{I=0} = -\infty$ and $c_I(q,\infty) = 0 \; \forall \; q$. The variable μ is a binary parameter that takes on the value 0 or 1.[10] The price-cap set by the regulator is given by $\bar{p}$. With consumer surplus defined by $S(p) = \int_p^\infty Q(z)dz$, the regulator's measure of consumer welfare is $W^c(p) = \beta S(p) + (1-\beta)(1-\alpha)\pi^A$.

The firm's general problem is to

$$(0) \qquad \underset{\{\alpha,e,I,p\}}{\text{Maximize}} \qquad \pi^R = \alpha\pi^A(p,e,I) - \psi(I),$$

subject to:

$$(1) \qquad p \le \bar{p},$$

$$(2) \qquad \alpha \in [0,1], \text{ and}$$

$$(3) \qquad e \in \underset{e'}{\text{argmax}} \left[W^c = \beta \int_p^\infty Q(z)dz + (1-\beta)(1-\alpha)\pi^A(p,e',I)\right].$$

Benchmark Solutions

The First-Best Case

We begin by establishing the benchmark first-best case. In this case, the firm's effort choice is publicly observed and entry can be contracted upon. Formally, the regulator's choice variables are α, e, p, I. The regulator's problem is to

$$(4) \qquad \underset{\{\alpha,e,p,I\}}{\text{Maximize}} \qquad W^c = \beta S + (1-\beta)(1-\alpha)\pi^A(p,e,I),$$

[10] Except where specifically noted, $\mu = 1$.

subject to:

(5) $\pi^R = \alpha\pi^A(p,e,I) - \psi(I) \geq 0$, and

(6) $\alpha \in [0,1]$,

where constraint (5) ensures that the incumbent firm is willing to operate in the regulated environment, and constraint (6) places bounds on feasible profit-sharing arrangements.

To begin, it is useful to characterize the optimal sharing rule.

Proposition 1: In the first-best case,

(i) if $\beta \in [½, 1]$, then $\alpha^* = 1$;

(ii) if $\alpha^* < 1$, then $\beta \in [0,½)$;

(iii) if $\beta = 0$, then $\alpha^* < 1$; and

(iv) $\pi^R = 0$.

Proof:

Proof of (i) and (ii): Substituting for S and $\pi^A(p,e,I)$, the Lagrangian is given by

(7) $$\mathcal{L} = \beta \int_p^\infty Q(z)dz + (1-\beta)(1-\alpha)[q(p,e)p - c(q,I)]$$

$$+ \lambda\Big[\alpha[q(p,e)p - c(q,I)] - \psi(I)\Big] + \xi[1-\alpha],$$

where λ and ξ are the Lagrange multipliers associated with (5) and (6), respectively. Maximizing with respect to α yields

(8) $[\lambda-(1-\beta)][q(p,e)p - c(q,I)] - \xi \leq 0$ and $\alpha[\mathcal{L}_\alpha] = 0$.

If $\mathcal{L}_\alpha < 0$, then $\alpha = 0$ and the participation constraint is violated. If $\alpha > 0$, equation (8) holds as an equality, or

(8′) $[\lambda-(1-\beta)][q(p,e)p-c(q,I)] - \xi = 0$.

It is straightforward to show that when the participation constraint binds, $\lambda \geq \max[\beta,1-\beta]$, and in the case of perfectly inelastic demand, $\lambda = \max[\beta,1-\beta]$. Suppose that $\max[\beta,1-\beta] = \beta$. From

(8′), the first term is positive, which for an interior solution implies that $\xi > 0$ and $\alpha^* = 1$. This proves (i). The contrapositive of (i) yields (ii). ■

Proof of (iii): Suppose that $\alpha^* = 1$ when $\beta = 0$. This implies that $W^c = 0$. But if $\alpha^* < 1$, then $W^c > 0 \; \forall \; I > 0$ contradicting $\alpha^* = 1$ as an optimum. ■

Proof of (iv): From (8′), if $\beta < 1$ and $\lambda = 0$, we have a contradiction and $\pi^R = 0$. If $\beta = 1$, then $\xi > 0$ which implies that $\lambda > 0$ and $\pi^R = 0$. ■

Examining the limit points for β provides some useful intuition. When $\beta = 1$, the regulator values only consumer surplus. Since the regulator does not value shared profits ($\beta = 1$), it provides the firm with the full share of profits. As a result, the regulator can set a relatively low price, thus maximizing consumer surplus, while still inducing the firm to participate.

When $\beta = 0$, the regulator values only shared profits. Here, the regulator will set a profit-maximizing price and set α at a level just sufficient to induce the firm to participate (assuming, of course, that maximal profit is sufficiently large). This implies that the profit share constraint does not bind.

For interior values of β, the logic is similar. For $\beta \geq (1-\beta)$, pure price-caps ($\alpha^* = 1$) are optimal since the regulator can choose a price that ensures consumer surplus exceeds shared profits. By the same reasoning, a necessary condition for sharing to be optimal ($\alpha^* < 1$) is that $\beta < (1-\beta)$. Hence, when a sharing rule is observed, it can be inferred that $\beta < ½$.

We now characterize the optimal choice of p, e and I.

Proposition 2: In the first-best case,

(i) the optimal price is decreasing with β for β sufficiently small;

(ii) $e^* = 0$: the regulator precludes competitive entry if $q_e(.) < 0$;[11] and

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[11] It is straightforward to show that when $q_e = 0$, price (p) and competitive entry (e) are identical policy instruments.

(iii) $-c_I = \psi'(I)$: the efficient level of effort is achieved.

Proof:

Proof of (i):

(9) $$\mathcal{L}_p = -\beta Q(p) + (1-\beta)(1-\alpha)[q_p(p,e)p + q(p,e) - c_q q_p(p,e)] + \lambda\Big[\alpha[q_p(p,e)p + q(p,e) - c_q q_p(p,e)]\Big] \le 0 \text{ and } p[\mathcal{L}_p] = 0.$$

Dividing equation (A3) through by q(p,e) and rearranging terms yields

(10) $$-\beta\gamma + [(1-\beta)(1-\alpha) + \alpha\lambda][(q_p/q)p + 1 - c_q(q_p/q)] = 0,$$

where $\gamma = Q(p)/q(p,e) \ge 1$. Note that $p > 0$ since with $p = 0$, $\pi \le 0$ and the participation constraint is violated. Hence the only feasible solution is an interior one. Substituting for ε_p in (10) yields

(11) $$-\beta\gamma + [(1-\beta)(1-\alpha) + \alpha\lambda]\Big[1 - \varepsilon_p[(p-c_q)/p]\Big] = 0.$$

Rearranging terms yields

(12) $$1 - \varepsilon_p[(p-c_q)/p] = \beta\gamma/[(1-\beta)(1-\gamma) + \alpha\lambda],$$

(12′) $$-\varepsilon_p[(p-c_q)/p] = \beta\gamma/[(1-\beta)(1-\gamma) + \alpha\lambda] - 1, \text{ and}$$

(12″) $$(p-c_q)/p = \Big[(1-\beta)(1-\alpha) + \alpha\lambda - \beta\gamma]/[(1-\beta)(1-\alpha) + \alpha\lambda]\Big]\Big[1/\varepsilon_p\Big].$$

Now let $\beta = 0$ so that the regulator values only shared profits. By previous arguments, we know that $\lambda = (1-\beta)$. Note that this implies from (12″) that $\beta < ½$. Under these conditions, (12″) becomes

(13) $$p-c_q/p = 1/\varepsilon_p,$$

which is the standard Lerner index. The regulator behaves as a profit-maximizing monopolist.

We know that for β sufficiently small, $\lambda = (1-\beta)$. The general expression for the optimal pricing rule under these conditions is given by

(14) $$p-c_q/p = [(1-\beta - \beta\gamma)/(1-\beta)][1/\varepsilon_p].$$

Rearranging terms and simplifying yields

(15) $p - c_q/p = [1 - \beta\gamma/(1-\beta)][1/\varepsilon_p]$.

Holding ε_p fixed,

(16) $\partial/\partial\beta\ \{p - c_q/p\} = [(-\gamma(1-\beta) - \beta\gamma)/(1-\beta)^2][1/\varepsilon_p] = -\gamma/(1-\beta)^2(1/\varepsilon_p) < 0$. ■

Proof of (ii):

(17) $$\mathcal{L}_e = -\beta p_e q(p) + (1-\beta)(1-\alpha)\Big[q_p p_e p + q_e p + p_e q(p) - c_q[q_p p_e + q_e]\Big]$$
$$+ \lambda\Big[\alpha[q_p p_e p + q_e p + p_e q - c_q[q_p p_e + q_e]]\Big] \leq 0; \text{ and } e[\mathcal{L}_e] = 0.$$

Dividing equation (17) through by $p_e < 0$ and rearranging provides

(18) $$-\beta Q(p) + (1-\beta)(1-\alpha)[q_p p + q - c_q q_p] + \lambda\alpha[q_p p + q(p) - c_q q_p]$$
$$+ [(1-\beta)(1-\alpha) + \lambda\alpha][p - c_q][q_e/p_e] \geq 0.$$

The first line of equation (18) is identical to equation (9), which is identically zero at an interior optimum. The second line of (18) is strictly positive if $p > c_q$ (required for satisfaction of the participation constraint) by (i) demand dissipation ($q_e < 0$) and (ii) $p_e < 0$. This implies that $\mathcal{L}_e < 0$, which, by complementary slackness, requires that $e^* = 0$. ■

Proof of (iii):

(19) $\mathcal{L}_I = -(1-\beta)(1-\alpha)c_I + \lambda[-\alpha c_I - \psi'(I)] = 0$.

A corner solution is ruled out by the assumed properties of the cost function. For β sufficiently small, $\lambda = (1-\beta)$ and (19) reduces to

(20) $-c_I = \psi'(I)$.

For $\beta = 1$, (19) reduces to

(21) $\alpha\lambda[-c_I] = \lambda\psi'(I)$.

By previous arguments, the profit-share constraint binds at $\beta = 1$ which implies that $\alpha = 1$. Hence, again

(22) $-c_I = \psi'(I)$,

and the efficient level of investment in effort is achieved. Recognize from the first-order condition on α that if $\lambda = (1-\beta)$, $\xi = 0$ and $\alpha \leq 1$; and if $\lambda \neq (1-\beta)$, $\xi > 0$ and $\alpha = 1$. This proves that the coefficients on $-c_I$ and $\psi'(I)$ in (19) are equal $\forall$ β. ■

As β increases from 0, the regulator increases his valuation of consumer surplus and decreases his valuation of shared profits. Hence, the regulator reduces price below the profit-maximizing level, which simultaneously lowers profits and increases consumer surplus.

The regulator can set price directly since p is a choice variable, or choose a positive level of entry (e) in order to bring about the desired market price indirectly. But the latter generates a negative externality for the regulator in the form of the demand dissipation effect ($q_e < 0$). By assumption, the regulator can tax the incumbent but not the entrant(s). Consequently, the use of e rather than p reduces the demand base upon which the regulator earns shared profits (tax revenues). Hence, relative to price (p), entry (e) is a strictly inferior policy instrument. It follows that as long as the regulator can choose p, he will set $e^* = 0$.

The Second-Best Case

We now investigate the second-best case in which I is not observed by the regulator.[12] This case entails perfect commitment by the regulator over entry (e). Formally, the regulator's choice variables are e, α and p (or $\bar{p}$), while the firm chooses I.[13] The regulator's problem is to

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[12] The second-best problem is nontrivial here because of the presumed policy instruments. If lump-sum, unbounded penalties could be imposed, and price could be conditioned on observed cost, the regulator could make the firm deliver the desired I by imposing a large penalty on the firm if dictated cost levels are not achieved.

[13] The firm chooses effort, I, to maximize realized profits, or

(0) $\quad I \in \underset{I'}{\operatorname{argmax}} \left[\alpha[q(p,e)p - c(q,I')] - \psi(I')\right].$

Differentiating the first-order condition with respect to price, p, yields

(1) $\quad dI/dp = c_I q_p/[-\alpha c_{II} - \psi''(I)] \leq 0,$

as $c_I < 0$, $q_p \leq 0$ and the denominator is negative since $\psi'' > 0$ and $c_{II} > 0$. The result that effort is decreasing (increasing) in price (output) has been termed the "Arrow Effect" following Arrow (1962).

(23) Maximize $\{\alpha,p,c,I\}$ $\quad W^c = \beta S + (1-\beta)(1-\alpha)\pi^A(.)$

subject to:

(24) $\pi^R = \alpha\pi^A(.) - \psi(I) \geq 0,$

(25) $\alpha \in [0,1]$, and

(26) $I \in \underset{I'}{\text{argmax}}\ [\alpha\pi^A(.) - \psi(I')].$

The fact that the firm does not choose p in the second-best problem stems from the fact that when the price-cap constraint binds, the regulator's ability to set $\bar{p}$ is de facto ability to set p.

Lemma 1: The price-cap constraint binds at the solution to the general second-best problem.

Proof: It suffices to show that $p \geq \bar{p}$, where p is the firm's optimal price and $\bar{p}$ is the optimal price-cap set by the regulator. The optimal choice of price for the regulator and the firm are given by

(27) $\bar{p} \in \underset{p'}{\text{argmax}} \Big[(1-\alpha)(1-\beta)[q(p',e)p'-c(q,I)]\Big]$, and

(28) $p \in \underset{p'}{\text{argmax}} \Big[\alpha[q(p',e)p'-c(q,I)] - \psi(I)\Big].$

The corresponding first-order condition for (27) is given by

(29) $[q_p p + q - c_q q_p - c_I(dI/dp)] = 0.$

Rearranging terms and substituting for ε_p yields

(30) $(\bar{p}-c_q)/\bar{p} = [1 - (c_I/q)(dI/dp)][1/\varepsilon_p].$

The corresponding first-order condition for (28) is given by

(31) $\alpha[q_p p + q - c_q q_p - c_I(dI/dp)] - \psi'(I)(dI/dp) = 0.$

Recognize that $dI/dp = 0$ by the Envelope Theorem, so that (31) reduces to

(32) $(p-c_q)/p = 1/\varepsilon_p$.

It can be shown that $dI/dp \leq 0$, and $c_I < 0$ by the properties of the firm's cost function. Comparing (30) and (32), it follows that $p \geq \bar{p}$. ■

We now proceed to characterize the optimal sharing rule (α).

Proposition 3: In the second-best case,

(i) if $\beta = 1$, then $\alpha = 1$; and

(ii) if $\beta = 0$, then $\alpha < 1$.

If demand is perfectly price-inelastic then,

(iii) if $\beta \in [\frac{1}{2}, 1]$, then $\alpha = 1$;

(iv) if $\alpha < 1$, then $\beta \in [0, \frac{1}{2})$; and

(v) $\pi^R \geq 0$.

Proof: Using the first-order approach to the firm's choice of effort, I, the Lagrangian is given by

(33) $$\mathcal{L} = \beta \int_p^\infty Q(z)dz + (1-\beta)(1-\alpha)[q(p,e)p - c(q,I)]$$
$$+ \lambda\Big[\alpha[q(p,e)p - c(q,I)] - \psi(I)\Big] + \phi[-\alpha c_I - \psi'(I)] + \xi[1-\alpha].$$

Consolidating terms and rewriting the Lagrangian, we obtain

(34) $$\mathcal{L} = \beta \int_p^\infty Q(z)dz + [(1-\beta)(1-\alpha) + \alpha\lambda][q(p,e)p - c(q,I)] - \lambda\psi(I)$$
$$+ \phi[-\alpha c_I - \psi'(I)] + \xi[1-\alpha].$$

(35) $$\mathcal{L}_\alpha = [-(1-\beta)+\lambda][q(p,e)p-c(q,I)]+[(1-\beta)(1-\alpha)+\alpha\lambda][-c_I(dI/d\alpha)]$$
$$-\lambda\psi'(I)(dI/d\alpha) + \phi[-c_I - \alpha c_{II}(dI/d\alpha) - \psi''(I)(dI/d\alpha)] - \xi \leq 0;\ \alpha[\mathcal{L}_\alpha] = 0.$$

Rewriting equation (35)

(35′) $$[\lambda-(1-\beta)][q(p,e)p - c(q,I)] + [(1-\beta)(1-\alpha)][-c_I(dI/d\alpha)] + \lambda[-\alpha c_I - \psi'(I)](dI/d\alpha)$$
$$+ \phi[-c_I - \alpha c_{II}(dI/d\alpha) - \psi''(I)(dI/d\alpha)] - \xi = 0.$$

The expression inside the brackets of the third term is precisely the incentive compatibility constraint. Hence, if $\phi > 0$, the third term vanishes, and if $\phi = 0$, the fourth term vanishes. The term inside the brackets of the fourth term is the first partial of the optimal level of effort (I) with respect to α. It can be shown that this expression has a positive sign. Hence, if $\lambda > 0$, the first four terms of (35′) are all nonnegative and at least one is strictly positive for $\beta \in [0,1]$. This implies that $\xi > 0$ and $\alpha = 1 \ \forall \ \beta$. ■

Proof of (i): Suppose that $\beta = 1$. The first three terms in (35′) are nonnegative and the fourth term is strictly positive. This implies that $\xi > 0$ and $\alpha = 1$. ■

Proof of (ii): We claim that for β sufficiently small, the condition, $\alpha = 1$, cannot hold at an optimum. Suppose that $\beta = 0$ so that the regulator places a weight of unity on shared profits. If $\xi > 0$ at $\beta = 0$, then the regulator's pay-off is identically zero since $(1-\beta)(1-\alpha)\pi^A = (1-0)(1-1)\pi^A = 0$. We claim that this is an optimum in order to arrive at a contradiction. Suppose that $\alpha < 1$. From (35′), an interior solution requires that the first term be strictly negative $\Rightarrow \lambda = 0$. But if $\lambda = 0$, then $\pi^R \geq 0 \Rightarrow \pi^A > 0 \ \forall \ I > 0$. Since $\alpha < 1$, $1-\alpha > 0$ which implies the regulator's pay-off is $(1-\alpha)(1-\beta)\pi^A = (1-\alpha)(1)\pi^A > 0$ which contradicts $\xi > 0$, $\alpha = 1$ as an optimum. Hence, $\xi = 0$ and $\alpha < 1$. ■

Proof of (iii) and (iv):

(36) $$\mathcal{L}_p = -\beta Q(p) + [(1-\beta)(1-\alpha) + \alpha\lambda][q(p)p + q - c_q q_p - c_I(dI/dp)]$$
$$-\lambda\psi'(I)(dI/dp) + \phi[-\alpha c_{II} - \psi''(I)][dI/dp] + \phi[-\alpha c_{Iq}q_p] = 0,$$

assuming an interior solution. Rearranging terms,

(36′) $$-\beta Q(p) + [(1-\beta)(1-\alpha) + \alpha\lambda][q_p(p-c_q) + q] + [(1-\beta)(1-\alpha)(-c_I)][dI/dp]$$
$$+ \lambda[-\alpha c_I - \psi'(I)][dI/dp] + \phi[-\alpha c_{II} - \psi''(I)][dI/dp] - \phi[\alpha c_{Iq}q_p] = 0.$$

The fourth term in (36′) vanishes if $\phi > 0$. Hence,

(37) $$-\beta Q(p) + [(1-\beta)(1-\alpha) + \alpha\lambda][q_p(p-c_q) + q] + [(1-\beta)(1-\alpha)(-c_I)][dI/dp]$$

$$+ \phi[-\alpha c_{II} - \psi''(I)][dI/dp] + \phi[-\alpha c_{Iq}q_p] = 0.$$

We assert for now (and subsequently prove) that e = 0 at an optimum so that Q(p) = q(p,0). Dividing equation (37) through by q(p), we obtain

$$(38) \quad -\beta+[(1-\beta)(1-\alpha) + \alpha\lambda][(q_p/q)(p-c_q) + 1]+[(1-\beta)(1-\alpha)(-c_I)][(dI/dp)(1/q)]$$

$$+ \phi[-\alpha c_{II} - \psi''(I)][(dI/dp)(1/q)] + \phi[-\alpha c_{Iq}][q_p/q] = 0.$$

Substituting for ε_p into (38), we obtain

$$(39) \quad -\beta+[(1-\beta)(1-\alpha) + \alpha\lambda][1 - \varepsilon_p(p-c_q)/p] + [(1-\beta)(1-\alpha)(-c_I)][(dI/dp)(1/q)]$$

$$+ \phi[-\alpha c_{II} - \psi''(I)][(dI/dp)(1/q)] + \phi\alpha c_{Iq}(\varepsilon_p/p) = 0.$$

Let demand become perfectly inelastic so that $\varepsilon_p = 0$. It can be shown that dI/dp = 0 when $\varepsilon_p = 0$. Equation (39) thus reduces to

$$(40) \quad -\beta + [(1-\beta)(1-\alpha) + \alpha\lambda] = 0.$$

From previous analysis, $\lambda > 0 \Rightarrow \alpha = 1$, so that (40) reduces to

$$(41) \quad -\beta + \lambda = 0.$$

Since $\lambda = \max[\beta, 1-\beta]$, (41) $\Rightarrow \beta \geq ½$. ■

Proof of (iv): If $\alpha < 1$, then $\lambda = 0$ and (40) reduces to

$$(42) \quad -\beta + (1-\beta)(1-\alpha) = 0.$$

Since $\alpha \in (0,1]$, satisfaction of (42) requires that $\beta < ½$. ■

Proof of (v): This follows directly from the proofs for (iii) and (iv) above. ■

The interpretation of these results is similar to those discussed in the first-best case. Here, the regulator must defer the choice of effort to the firm. This allows for the possibility that realized profits are positive. In the case of perfectly inelastic demand, the (indeterminant) effort effects disappear and the results are identical to the first-best case.

Proposition 4. In the second-best case,

(i) $e = 0$ if $q_e < 0$;

(ii) $-c_I = \psi'(I)$, if $\alpha = 1$; and

(iii) $-c_I > \psi'(I)$, if $\alpha < 1$.

Proof: The proof for (i) is similar in technique, though considerably longer and more tedious, to the first-best result in proposition 2 part (ii) and is therefore omitted. For the proofs of (ii) and (iii), recognize that $-c_I = \psi'(I)$ when $\alpha = 1$, $-c_I > \psi'(I)$ when $\alpha < 1$ and appeal to proposition 3.

■

The interpretation here is similar to that provided for the first-best case. If the regulator can set price directly, it is inefficient to employ competitive entry in order to set price indirectly. The efficient level of effort is obtained only if $\alpha = 1$, otherwise, the firm underinvests in cost-reducing effort.

Principal Findings

In the general third-best problem, the firm chooses α and I, and the regulator chooses p (and e). The firm is the Stackelberg leader in this problem in the sense that the regulator reacts to the firm's choice of sharing rule (α) with a choice of price (p).[14] The firm anticipates the reaction of the regulator. Hence, in order to induce the regulator to choose a higher price, or to adopt a more conservative entry policy, the firm must provide the regulator with a vested interest in its financial performance. The firm provides such a vested interest by sharing its profits. The firm's problem is to

(43) $$\underset{\{\alpha,I,e\}}{\text{Maximize}} \quad \pi^R = \alpha[q(p,e)p(e) - c(q,I)] - \psi(I),$$

subject to:

[14] In the telecommunications industry, it is common for the firm to propose a particular regulatory regime (i.e., choice of sharing rule, α). Once the regulatory regime is in place, the regulator adopts a given competitive entry policy (e). The timing in the third-best case thus conforms with institutional reality.

(44) $p(e) \leq \bar{p}$,

(45) $\alpha \in [0,1]$, and

(46) $$e \in \underset{e'}{\operatorname{argmax}} \left[\beta \int_{p}^{\infty} Q(z)dz + [(1-\beta)(1-\alpha)][q(p,e')p(e')-c(q,l)] \right],$$

(47) subject to: $\alpha[q(p,e')p(e')-c(q,l)] - \psi(l) \geq 0$.

A number of preliminary observations are in order with regard to the structure of this problem. First, the functional dependence of p on e indicates that in this model the regulator may affect price only indirectly through e. Second, it is necessary to subconstrain the incentive compatibility constraint (46), which defines the regulator's entry decision, to preclude the regulator from adopting competitive entry policies that cause the regulated firm to shut down. Third, the price-cap, $\bar{p}$, is exogenous. This treatment abstracts from the effect that more generous profit-sharing might have on the price-cap, thereby focusing on the direct effect of profit-sharing on entry policy. Finally, it is necessary to impose the condition that $p(\tilde{e}) \leq \bar{p}$ for some $\tilde{e}$, so that it is within the regulator's control to satisfy the price-cap constraint. This formulation of the firm's problem clearly reveals the implicit recontracting problems associated with a price-cap regulatory regime when the regulator controls the terms of competitive entry.

To begin to characterize the solution to this problem, we abstract from the demand dissipation effect (by setting $q_e = 0$) and the firm's effort choice (so that $\mu = 0$, ensuring $l = 0$). In this Third-Best Problem-1, the firm's problem is to

(48) $$\underset{\{\alpha,p\}}{\text{Maximize}} \quad \pi^R = \alpha[q(p)p-c(q)],$$

subject to:

(49) $\alpha \in [0,1]$, and

(50) $p \in \underset{p'}{\operatorname{argmax}} \left[\beta \int_{p'}^{\infty} Q(z)dz + [(1-\beta)(1-\alpha)][q(p')p'-c(q)] \right],$

(51) subject to: $\alpha[q(p')p'-c(q)] \geq 0.$

The following lemma allows us to identify conditions under which the firm's choice of sharing rule influences the regulator's choice of price.

Lemma 2. If $W^c(p)$ is strictly concave and demand is inelastic ($\boldsymbol{\varepsilon}_p < 1$), then $p_\alpha < 0$.

Proof: The regulator chooses the optimal price according to

(52) $p \in \underset{p'}{\operatorname{argmax}} \left[\beta \int_{p}^{\infty} Q(z)dz + [(1-\beta)(1-\alpha)][q(p')p'-c(q)] \right].$

Differentiating (52) with respect to p, we obtain

(53) $-\beta Q(p) + [(1-\beta)(1-\alpha)][q_p(p-c_q) + q] = 0.$

An interior solution requires that

(54) $\alpha < 1-\left[\beta/[1-\beta][1-\boldsymbol{\varepsilon}_p(p-c_q)/p]\right].$

Concavity of $W^c(p)$ requires that

(55) $\alpha < 1- \beta/[(q_{pp}/q_p)(p-c_q) + (1-c_{qq}q_p)] + 1][(1-\beta)].$

In the case of linear demand and constant marginal cost of production, $q_{pp} = c_{qq} = 0$, equation (55) reduces to

(56) $\alpha < 1-\beta/2(1-\beta).$

It is straightforward to show that

(56′) $\alpha < 1-\left[\beta/[1-\beta][1-\boldsymbol{\varepsilon}_p(p-c_q)/p]\right] < 1-\beta/2(1-\beta) = (2-3\beta)/(1-\beta),$

so that $W^c(p)$ admits an interior solution implies $W^c(p)$ is strictly concave. Differentiating (53), the regulator's optimal choice of price, with respect to α, we obtain

(57) $\quad -\beta q(p)p_\alpha - (1-\beta)[q_p(p-c_q) + q] + [(1-\beta)(1-\alpha)][q_{pp}p_\alpha(p-c_q)]$

$\quad + q_p(p_\alpha - c_{qq}q_p p_\alpha)] = 0.$

Solving equation (57) for p_α, we obtain

(57′) $\quad p_\alpha = [(1-\beta)][q_p(p-c_q)+q] / \left[-\beta q_p + [(1-\beta)(1-\alpha)][q_{pp}(p-c_q)+q_p(1-c_{qq}q_p)+q_p]\right].$

The denominator on the right-hand side of (57′) is negative if $W^c(p)$ is concave. The numerator on the right-hand side of (57′) is positive if

(58) $\quad q_p(p-c_q) + q > 0.$

Dividing (58) through by q, we obtain

(59) $\quad (q_p/q)(p-c_q) + 1 > 0.$

Substituting for $\boldsymbol{\varepsilon}_p$ in (59) we obtain

(59′) $\quad 1 - \boldsymbol{\varepsilon}_p(p-c_q)/p > 0$, or

(59″) $\quad \boldsymbol{\varepsilon}_p(p-c_q)/p < 1.$

A sufficient condition for (59″) to be satisfied is that $\boldsymbol{\varepsilon}_p < 1$, or demand be price-inelastic.

It follows then that if demand is inelastic ($\boldsymbol{\varepsilon}_p < 1$) and $W^c(p)$ is concave, then

(60) $\quad p_\alpha < 0.$ ■

Here, inelastic demand is necessary to ensure that shared profits are strictly increasing with market price.

The following lemma establishes the firm's benchmark level of profits under pure PC regulation.

Lemma 3: In the Third-Best Problem-1, the firm earns zero realized profits under pure price-caps ($\alpha = 1$).

Proof: The Lagrangian for the regulator's subconstrained optimization problem is

(61) $$\mathfrak{L} = \beta \int_p^\infty Q(z)dz + [(1-\beta)(1-\alpha)][q(p)p-c(q)] + \lambda\left[\alpha[q(p)p-c(q)]\right].$$

Consolidating terms, we obtain

(62) $$\mathcal{L} = \beta \int_{p}^{\infty} Q(z)dz + [(1-\beta)(1-\alpha)+\alpha\lambda][q(p)p-c(q)].$$

Imposing the pure price-cap ($\alpha = 1$) condition,

(63) $$\mathcal{L} = \left[\beta \int_{p}^{\infty} Q(z)dz + \lambda[q(p)p-c(q)]\right].$$

Differentiating (63) with respect to price, we obtain

(64)) $$-\beta q(p) + \lambda[q_p(p-c_q) + q] = 0.$$

Since $\beta > 0$ (by assumption) and $q(p) > 0$, a necessary condition for an interior optimum is that $\lambda > 0$ which implies that $\pi^R = 0$, or the firm earns precisely zero realized profits. ■

Lemma 3 establishes that the regulator will set a price under pure PC regulation that just prevents shutdown of the firm. When the firm chooses pure PC regulation ($\alpha = 1$), it severs the regulator's vested interest in its financial performance.

Having established that the firm can do no better than break even under pure price-caps ($\alpha = 1$), we now turn to the question of whether the firm can earn strictly positive realized profits under profit-sharing ($0 < \alpha < 1$).

Proposition 5: If $q_{pp} = c_{qq} = 0$ and $\beta/1-\beta < 1 - [2\varepsilon_p/(1+\varepsilon_p^2)]$, there exists an $\alpha \in (0,1)$ such that $\pi^R > 0$ in the solution to the Third-Best Problem-1.

Proof: Note that $p = c_q$ for $\alpha = 1$ and appeal to the proof of proposition 6. ■

Proposition 5 establishes conditions under which the firm can realize higher profits under profit-sharing than under pure price-caps. Figure 3-2 illustrates this result. For $\alpha \in (0,\alpha^*)$, the regulator will choose a price greater than marginal cost when the firm agrees to share profits with consumers. The result is strictly positive realized profits for the firm. Here, a "greed strategy" (i.e., zero sharing) is self-defeating in the sense that the firm succeeds only in retaining one

hundred percent of zero profits.[15] This result illustrates the recontracting problem with PC regulation. When entry cannot be contracted upon (and $q_e = 0$), entry (e) and price (p) are identical policy instruments. Hence, in choosing α, the firm is affecting the absolute level of profits as well as its distribution. Setting $\mu = 0$ suppresses the firm's choice of effort in this problem, which avoids the indeterminacy that arises when effort affects variable costs.

We turn next to analysis of the third-best problem in which the firm chooses the level of effort (I) so that $\mu = 1$. In this formulation of the problem, we assume that effort affects the fixed costs of production, but not variable costs, so that the firm's (observed) cost function is of the form $C(q,I) = F(I) + c(q)$, where $F(I)$ denotes fixed costs with $F_I < 0$ and $F_{II} > 0$. In addition, we assume an interior level of effort arises, as will be the case, for example, if $F_I(q,I)|_{I=0} = -\infty$ and $F_I(q,\infty) = 0 \ \forall\ q$.

We refer to this problem as the Third-Best Problem-II:

(65) $$\underset{\{\alpha,p,I\}}{\text{Maximize}} \qquad \pi^R = \alpha[q(p)p-C(q,I)] - \psi(I),$$

subject to:

(66) $\alpha \in [0,1]$, and

(67) $$p \in \underset{p'}{\text{argmax}} \left[\beta \int_{p'}^{\infty} Q(z)dz + [(1-\beta)(1-\alpha)][q(p')p'-C(q,I)] \right],$$

(68) subject to: $\alpha[q(p')p'-C(q,I)] - \psi(I) \geq 0$.

We begin again by examining how the regulator's optimal choice of price, p, varies with the firm's choice of sharing rule, α.

Lemma 4: If $W^c(p)$ is strictly concave and demand is inelastic, then $p_\alpha < 0$ in the Third-Best Problem-II.

[15] It is important to emphasize here that the firm does not share in order to increase the price-cap, as this is fixed. The firm shares in order to discipline the actions of the regulator (i.e., to discourage adoption of liberal entry policies).

Proof: The first-order approach to the regulator's optimal choice of price yields

(69) $\quad -\beta Q(p) + [(1-\beta)(1-\alpha)][q_p(p-c_q) + q - F_I(dI/dp)] = 0,$

where the participation constraint is initially omitted. It can readily be shown that $dI/dp = 0$ since $c_I(q) = 0$ so that (69) can be written as

(70) $\quad -\beta q(p) + [(1-\beta)(1-\alpha)][q_p(p-c_q) + q] = 0,$

which is identical to (53) in the proof of lemma 2. The remainder of the proof is identical to that provided in lemma 2 and is therefore omitted. ■

Lemma 5: In the Third-Best Problem-II, the firm earns zero realized profits under pure price-caps ($\alpha = 1$), and so sharing rules ($0 < \alpha < 1$) weakly dominate pure price-caps ($\alpha = 1$).

Proof: Recognizing that $dI/dp = 0$, the first part of the proof is identical to that provided for lemma 3 and is therefore omitted. If the participation constraint binds, then $\pi^R = 0$. If the participation constraint does not bind then $\pi^R \geq 0$. ■

We proceed now to determine the conditions under which the firm can realize strictly higher profits under sharing than under pure price-caps. Our main finding is stated formally in the next proposition.

Proposition 6: If $q_{pp} = c_{qq} = 0$ and $\beta/[1-\beta] < (\varepsilon_p-1)^2[1-\varepsilon_p(p-c_q)/p]/[(1+\varepsilon_p^2)]$, there exists an $\alpha \in (0,1)$ such that $\pi^R > 0$ in the solution to the Third-Best Problem-II.

Proof:

(71) $$d\pi^R = [q(p)p-F(I)-c(q)-\alpha F_I(dI/d\alpha)-\psi'(I)(dI/d\alpha)]d\alpha$$
$$+ \alpha\Big[[q_p(p-c_q) + q - F_I(dI/dp)] - \psi'(I)(dI/dp)\Big]dp = 0.$$

Recall that $dI/d\alpha = 0$ by the Envelope Theorem and $dI/dp = 0$ so that (71) reduces to

(72) $\quad d\pi^R/dp = [q(p)p - F(I) - c(q)]d\alpha/dp + \alpha[q_p(p-c_q) + q].$

Hence, the gradient of the firm's iso-profit locus is

(73) $dp/d\alpha|_{\pi^R=0} = \underline{p}_\alpha = -[q(p)p-F(1)-c(q)]/\alpha[q_p(p-c_q) + q(p)] < 0.$

See Figure 3-3. Let $\underline{p}(\alpha)$ be the regulated price such that, given α, $\pi^R = 0$.

The regulator's optimal choice of price varies with α in the unconstrained case according to

(74) $p^*_\alpha = [(1-\beta)][q_p(p-c_q)+q]/\left[-\beta q_p+[(1-\beta)(1-\alpha)][q_{pp}(p-c_q)+q_p(1-c_{qq}q_p)+q_p]\right].$

We note that $p^*_\alpha < 0$ if demand is inelastic and the concavity condition is satisfied. Let $p^*(\alpha)$ define the regulator's optimal (unconstrained) choice of price conditioned on the firm's choice of α. Let $p(\alpha)$ define the effective price set by the regulator for each choice of α by the firm. It follows that

(75) $p(\alpha) = \max\{\underline{p}(\alpha), p^*(\alpha)\}.$

The reasoning is as follows. If the regulator sets $p(\alpha) < \underline{p}(\alpha)$, the firm's participation constraint is violated. Hence, price can never be set less than $\underline{p}(\alpha)$. If $p^*(\alpha) > \underline{p}(\alpha)$, W^c is higher at $p^*(\alpha)$ than it is at $\underline{p}(\alpha)$. But if $p^*(\alpha) > \underline{p}(\alpha)$, then $\pi^R > 0$ and $\lambda = 0$.

We derive conditions for $p^*(\alpha) > \underline{p}(\alpha)$, proceeding as follows:

(1) Observe that $p(\alpha) \geq \underline{p}(\alpha)$.

(2) Determine the conditions under which $|p^*_\alpha| > |\underline{p}_\alpha|$.

(3) Determine if the conditions in (2) hold on a nondegenerate interval.

(4) Conclude that $\exists\ \alpha \in (0,1)$ for which $p^*(\alpha) > \underline{p}(\alpha) \Rightarrow \pi^R > 0 \Rightarrow$ sharing dominates pure price-caps.

In the case of linear demand and constant marginal cost of production, $q_{pp} = c_{qq} = 0$. Equation (74) reduces to

(76) $p^*_\alpha = [(1-\beta)][q_p(p-c_q) + q]/[-\beta q_p + 2(1-\beta)(1-\alpha)q_p],$

and recall that

(77) $\underline{p}_\alpha = -[q(p)p-F(1)-c(q)]/\alpha[q_p(p-c_q) + q(p)] < 0.$

Let

(78) $\quad \tilde{\underline{p}}_\alpha = -[q(p)p]/\alpha[q_p(p-c_q) + q(p)] < 0.$

Recognize now that $|\tilde{\underline{p}}_\alpha| > |\underline{p}_\alpha|$, since $F(I) + c(q) > 0$. Dividing equation (78) through by q, we obtain

(79) $\quad \tilde{\underline{p}}_\alpha = -p/\alpha[(q_p/q)(p-c_q)+1].$

Upon substitution of $\boldsymbol{\varepsilon}_p$,

(80) $\quad \tilde{\underline{p}}_\alpha = -p/\alpha[1-\boldsymbol{\varepsilon}_p(p-c_q)/p].$

Dividing equation (80) through by q,

(81) $\quad p^*_\alpha = \left[[(1-\beta)][(q_p/q)(p-c_q)+1]\right]/[2(1-\beta)(1-\alpha)-\beta][(q_p/q)].$

Upon substitution of $\boldsymbol{\varepsilon}_p$,

(82) $\quad p^*_\alpha = -[(1-\beta)][1-\boldsymbol{\varepsilon}_p(p-c_q)/p]/[2(1-\beta)(1-\alpha)-\beta][\boldsymbol{\varepsilon}_p/p].$

Multiplying through by p,

(83) $\quad p^*_\alpha = -[(1-\beta)][p-\boldsymbol{\varepsilon}_p(p-c_q)]/[2(1-\beta)(1-\alpha)-\beta]\boldsymbol{\varepsilon}_p.$

The relevant comparison is between equations (80) and (83). We explore sufficient conditions for $|p^*_\alpha| > |\tilde{\underline{p}}_\alpha|$, or

(84) $\quad [(1-\beta)][p-\boldsymbol{\varepsilon}_p(p-c_q)]/[2(1-\beta)(1-\alpha)-\beta]\boldsymbol{\varepsilon}_p > p/\alpha[1-\boldsymbol{\varepsilon}_p(p-c_q)/p].$

Multiplying the numerator and denominator on the right-hand side by p,

(85) $\quad [(1-\beta)][p-\boldsymbol{\varepsilon}_p(p-c_q)]/[2(1-\beta)(1-\alpha)-\beta]\boldsymbol{\varepsilon}_p > p^2/\alpha[p-\boldsymbol{\varepsilon}_p(p-c_q)],$

(86) $\quad \alpha[(1-\beta)][p-\boldsymbol{\varepsilon}_p(p-c_q)]^2 > p^2[2(1-\beta)(1-\alpha)-\beta]\boldsymbol{\varepsilon}_p,$

(87) $\quad \alpha[(1-\beta)][1-\boldsymbol{\varepsilon}_p(p-c_q)/p]^2 > [2(1-\beta)(1-\alpha)-\beta]\boldsymbol{\varepsilon}_p,$

(88) $\quad \alpha[1-\boldsymbol{\varepsilon}_p(p-c_q)/p]^2 > 2(1-\alpha)\boldsymbol{\varepsilon}_p \geq 2[(1-\beta)(1-\alpha)-\beta]\boldsymbol{\varepsilon}_p,$

(89) $\quad \alpha[1-\boldsymbol{\varepsilon}_p(p-c_q)/p]^2 > 2(1-\alpha)\boldsymbol{\varepsilon}_p$, and

(90) $\quad \alpha[1-\boldsymbol{\varepsilon}_p(p-c_q)/p]^2 > \alpha(1-\boldsymbol{\varepsilon}_p)^2 > 2(1-\alpha)\boldsymbol{\varepsilon}_p,$

since $(p-c_q)/p < 1$. Expanding the middle term in (90),

(91) $\alpha(1-2\varepsilon_p+\varepsilon_p^2) > 2(1-\alpha)\varepsilon_p$,

(92) $\alpha(1-2\varepsilon_p+\varepsilon_p^2)-2\varepsilon_p+2\alpha\varepsilon_p > 0$, and

(93) $\alpha(1+\varepsilon_p^2)-2\varepsilon_p > 0$.

Solving (93) for α,

(94) $\alpha > 2\varepsilon_p/(1+\varepsilon_p^2)$.

Let $\underline{\alpha} = 2\varepsilon_p/(1+\varepsilon_p^2)$. By lemma 2, $W^c(p)$ admits an interior solution when

(95) $\alpha < 1-\left[\beta/[1-\beta][1-\varepsilon_p(p-c_q)/p]\right]$.

Let $\bar{\alpha} = 1-\left[\beta/[1-\beta][1-\varepsilon_p(p-c_q)/p]\right]$. Hence, if the exogenous two-tuple (β,ε_p) defines a nondegenerate interval such that $\underline{\alpha} < \bar{\alpha}$, $\exists\ \alpha \in (\underline{\alpha}, \bar{\alpha})$ such that $|p_\alpha^*| > |\underline{p}_\alpha| \Rightarrow p^*(\alpha) > \underline{p}(\alpha) \Rightarrow \pi^R > 0$. It follows that the firm earns higher profits under sharing $(0 < \alpha < 1)$ than under pure price-caps $(\alpha = 1)$. ■

Figure 3-4 illustrates the relationship between the gradient of the iso-profit locus $(\underline{p}_\alpha)$ and the gradient of price along the iso-welfare locus (p_α^*). If $\underline{\alpha} < \bar{\alpha}$, there exists a sharing rule $(0 < \alpha < 1)$ for which p_α^* diverges from $\underline{p}_\alpha$ and the firm earns strictly positive realized profits. ■

The cost incurred by the regulator when he raises price (reducing consumer surplus) is increasing in both β and ε_p. Hence, if demand is relatively inelastic and the regulator's weight on consumer surplus is not too large, the firm's profits will be higher under sharing than under pure price-caps. Figure 3-5 illustrates the values of β and ε_p for which profit-sharing leads to strictly positive realized profits for the firm.

Corollary to Proposition 6: For $\beta = \varepsilon_p = 0$, the firm earns strictly positive realized profits $\forall\ \alpha \in (0,1)$.

Proof: Appeal to the proof of proposition 6, and note that $\beta = \varepsilon_p = 0 \Rightarrow (\underline{\alpha}, \bar{\alpha}) = (0,1)$. ■

Conclusion

The focus of the incentive regulation literature has been on how best to discipline the regulated firm. Here, we have examined how the firm's choice of sharing rule can serve to discipline the regulator's choice of price or competitive entry. This led to our major result that if demand is relatively inelastic and the regulator's weight on consumer surplus is not too large, the firm's profits will be higher under sharing than under pure price-caps. Hence, the finding that sharing is a dominant strategy for the firm, or less is more.

The fact that regulated firms consider sharing rules a capricious repatriation of earnings suggests that the strategic implications of sharing are not well understood. There is a tendency for the firm to confuse the regulator's commitment not to lower the price-cap with the regulator's commitment not to lower market price. Yet, if the regulator controls the terms of competitive entry and competition is effective in reducing market price, the price-cap commitment is de facto no commitment at all. In fact, a price-cap commitment may be worse than no commitment at all because the regulator is forced to lower price indirectly with an inferior policy instrument (i.e., competitive entry). Paradoxically, the regulator's willingness to honor the price-cap commitment can be harmful to the firm.

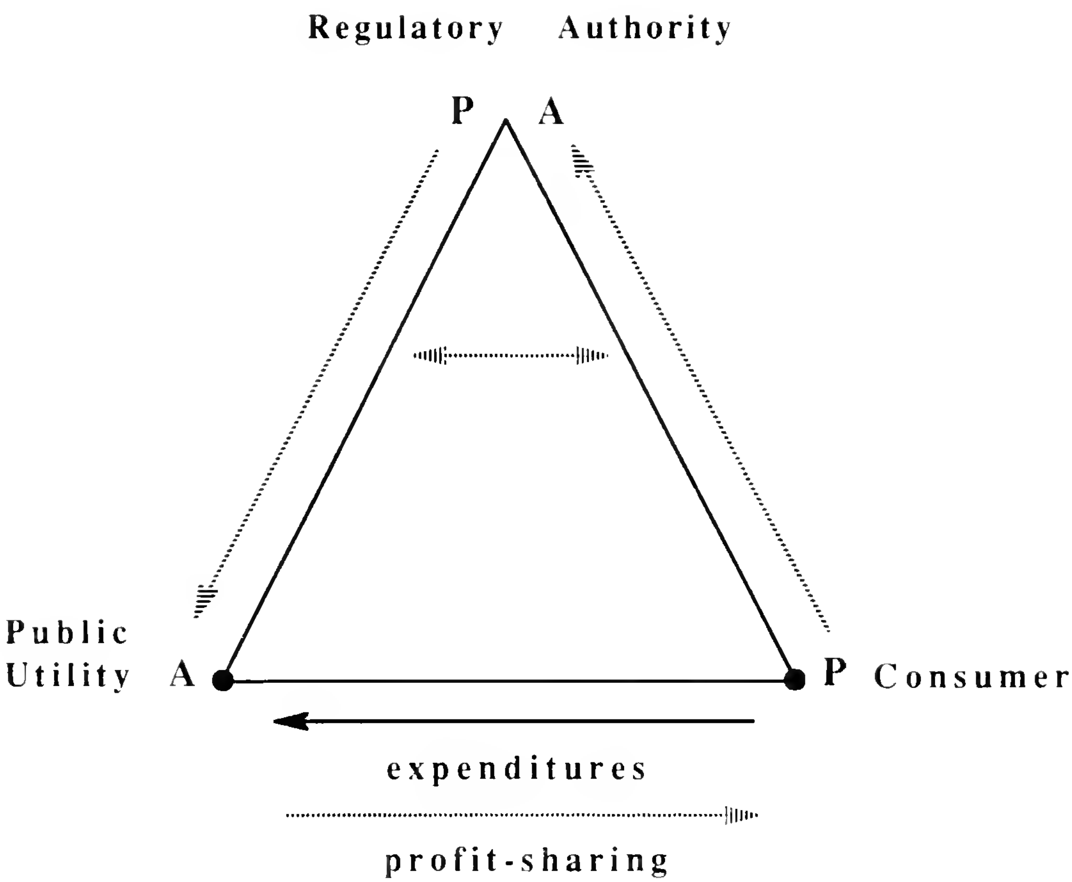

Figure 3-1: Profit-Sharing as a Means to Exert Upstream Control.
(P = Principal, A = Agent)

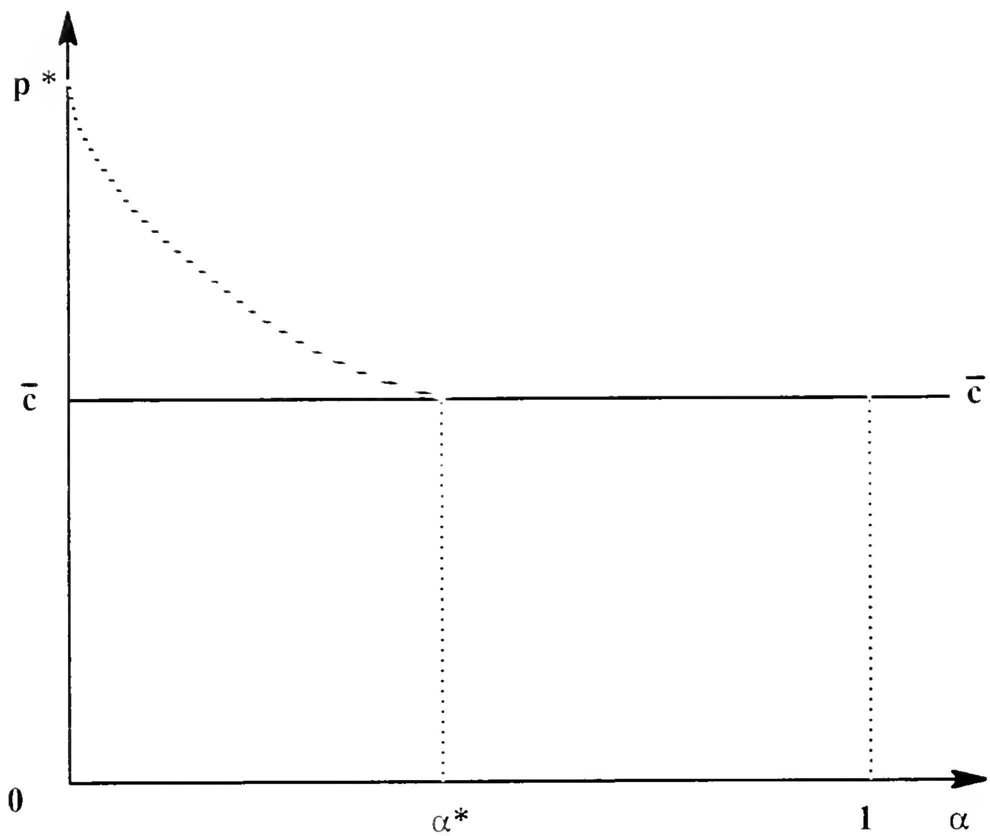

Figure 3-2: Feasible Values of α for $p_\alpha < 0$.

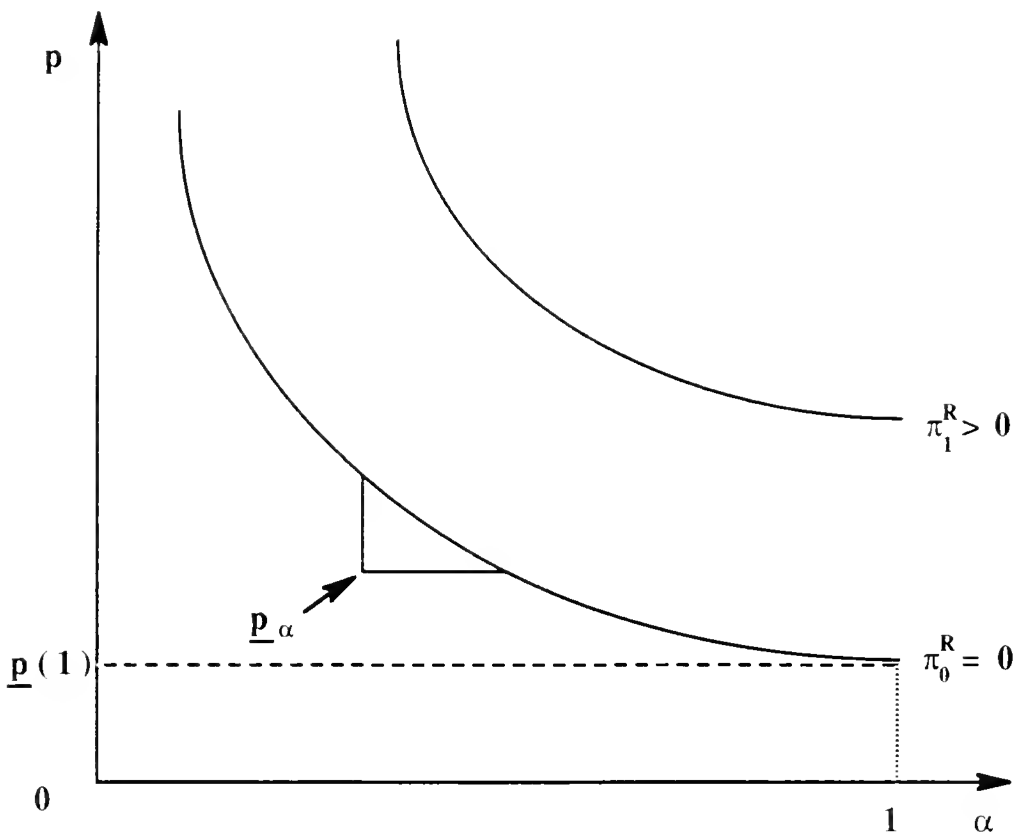

Figure 3-3: Firm's Iso-Profit Loci.

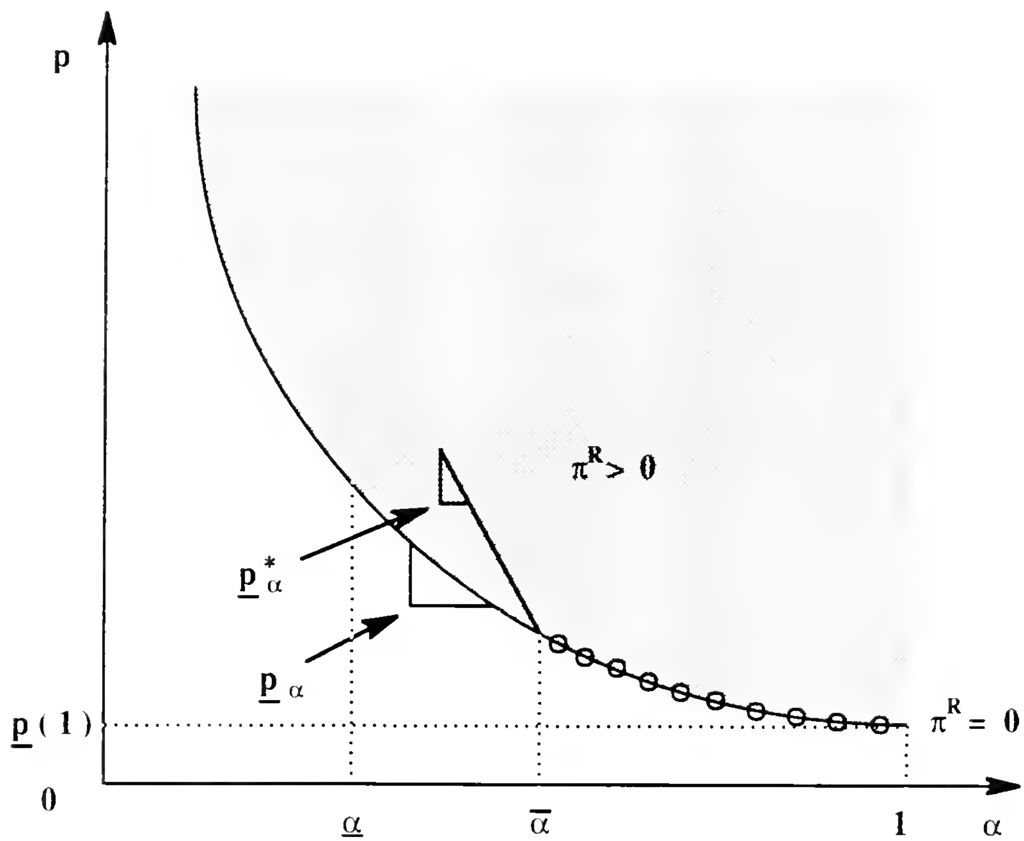

Figure 3-4: Gradient Comparison of p^*_α and $\underline{p}_\alpha$.

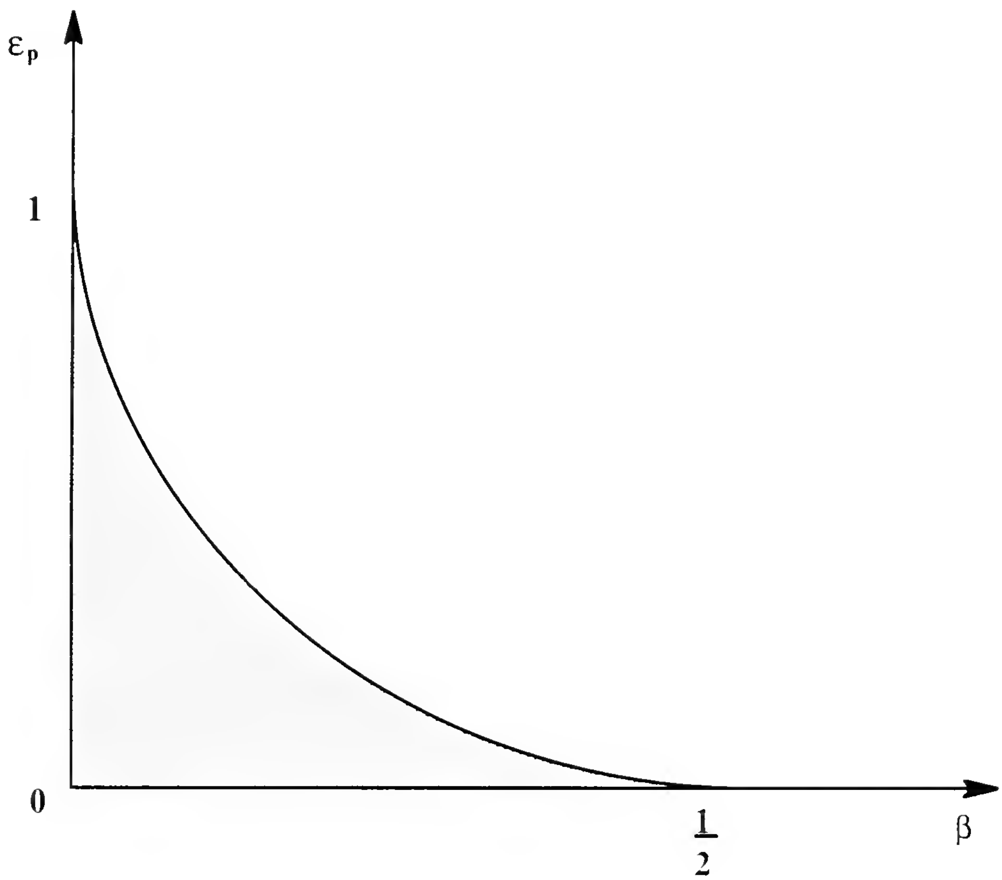

Figure 3-5: Feasible Region for (β, ε_p) that Define Nondegenerate Intervals for ($\underline{\alpha}$, $\overline{\alpha}$).

CHAPTER 4
DESIGNING CARRIER OF LAST RESORT OBLIGATIONS

Introduction

The advent of competition in regulated industries, such as telephone, electric power and natural gas, has caused economists to study the effects of asymmetric regulation on social welfare.[1] This research has examined the effect of constraining the (regulated) incumbent firm to honor historical public utility obligations, while allowing competitive entry. These historical obligations generally take the form of broadly averaged service rates, extensive tariff review processes in formal regulatory proceedings and carrier of last resort (COLR) obligations. It is the COLR obligation that is the focus of the formal analysis here.

The COLR obligation dates back to the Railway Act of 1920 which prohibited railroads from abandoning certain routes absent the issuance of a certificate of convenience and necessity from the Interstate Commerce Commission (ICC). The ICC was generally reluctant to issue such certificates if consumers were harmed by such abandonment, even when the continuation of service proved financially burdensome to the railroads.[2]

In the case of traditional public utility services, the COLR obligation essentially charges the incumbent firm with responsibility for standing by with facilities in place to serve consumers on demand, including customers of competitors. The historical origins of this obligation are significant because it is the asymmetry of this obligation that is the source of the market

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[1] See for example Haring (1984) and Weisman (1989a).

[2] See Goldberg (1979) p. 150 and notes 18-20 and Keeler (1983) pp. 38-39.

distortion. A public utility with a franchised right to serve a certificated geographic area maintains a responsibility to serve all consumers on demand. Yet, at least historically, there was a corresponding obligation on the part of consumers to be served by this public utility. As Victor Goldberg (1976) has argued, this form of administrative contract relied upon a form of reciprocity (symmetrical entitlements) which balanced the utilities' obligation to serve with the consumers' obligation to be served.[3] This balance evolved over time as a fundamental tenet of the regulatory compact. Regulators have been reluctant to relieve the incumbent of its COLR obligation in the face of competitive entry over concern that consumers could be deprived of access to essential services.[4]

Alfred Kahn (1971) first recognized that a nondiscriminatory COLR obligation might well handicap the incumbent firm. The context was MCI's entry into the long-distance telephone market in competition with AT&T. The exact citation is revealing.

> It is this problem that is the most troublesome aspect of the MCI case and others like it. If such ventures are economically feasible only on the assumption that when they break down or become congested subscribers may shift over to the Bell System for the duration of the emergency, they are indeed supplying an only partial service. If the common carrier is obliged to stand ready to serve and must carry the burden of excess capacity required to meet that obligation, it would seem that its average total costs would necessarily be higher than those of a private shipper or cream-skimming competitor who has no such obligation: the latter can construct capacity merely sufficient for operation at 100 percent load factors, with the expectation that it or its customers can turn to the common carriers in case of need. (Kahn, 1971, p. 238)

Weisman (1989b, p. 353) makes a similar observation with regard to more recent competitive entry in carrier access markets.[5] An interesting question for analysis concerns

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[3] See Goldberg (1976, 1979) and Weisman (1989a).

[4] For a case study of this phenomenon, see Weisman (1989c).

[5] An alternative viewpoint is offered by a recent competitive entrant in the carrier access market. See Metropolitan Fiber Systems (1989, pp. 67-70). The carrier access market in the telephone industry refers generically to the local access component of both the originating and

whether an entrant will choose to strategically exploit the incumbent's COLR obligation by underinvesting or overinvesting in reliability.[6]

The COLR issue per se has received little attention in the formal economic literature. Weisman (1988) discusses the distortions caused by the utilities' COLR obligation and recommends default capacity tariffs as a possible solution. Under this proposal, the subscriber purchases service under a two-part tariff. The first part of the tariff is a capacity charge that varies directly with the level of capacity purchased. The utility is responsible for capital outlays no greater than the collective demand for capacity across the universe of subscribers. The second part of the tariff is a usage charge. The subscriber's total usage is limited by the level of capacity purchased. Panzar and Sibley (1978) find that self-rationing, two-part tariffs of this type possess desirable efficiency properties.[7]

As a matter of positive economics, however, regulators have been reluctant to force consumers to bear the risk of self-rationing demand. Consequently, the set of instruments presumed available in the literature may be politically unacceptable in practice. Here, we intentionally restrict the set of viable policy instruments to correspond with current regulatory practice. This modeling convention facilitates a clear understanding of fringe competitor strategies while offering practical guidance on the design of efficient regulatory policies.

The primary objectives of this paper are to characterize the optimal COLR obligation and pricing rules in an environment where the incumbent firm faces a competitive fringe. We find

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terminating ends of long distance calls. Entrants in this market also supply digital, point-to-point dedicated circuits within a local calling area. These competitors are sometimes referred to as competitive access providers (CAPs).

[6] It is a noteworthy contrast that early entrants in the long distance telephone market supplied relatively unreliable service, whereas recent entrants in the carrier access and local distribution market supply what is purported to be a relatively superior grade of service.

[7] See also Spulber (1990).

that when the competitive fringe is relatively reliable, imposing a COLR constraint (asymmetrically) on the incumbent firm tends to lower the optimal price. Moreover, when the fringe is allowed to choose its reliability strategically, the optimal price is further reduced. A principal finding is that the competitive fringe has incentives to overcapitalize (undercapitalize) in the provision of reliability when the COLR obligation is sufficiently low (high).[8] Here, (COLR) supply creates its own demand in the sense that the need for a COLR may be validated as a self-fulfilling prophecy in equilibrium.

With a low COLR requirement, the regulator responds to increased unreliability on the part of the fringe by lowering price so as to retain a larger amount of output with the (reliable) incumbent. The competitive fringe can thus increase price by increasing reliability, ceteris paribus. With a high COLR requirement, an increase in reliability will reduce default output since the fringe serves a larger share of traffic diverted from the incumbent. The effective price elasticity for the incumbent therefore increases with fringe reliability which implies that the optimal price decreases with fringe reliability.

The analysis proceeds as follows. The elements of the formal model are developed in the second section. The benchmark results are presented in the third section. In the fourth section, we present our principal findings. The conclusions are drawn in the fifth section.

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[8] In general, we cannot discern whether the fringe is (over-) undersupplying reliability merely by observing its reliability relative to the incumbent. The determination of the efficient level of reliability naturally turns on whether the fringe invests in reliability up to the point where the marginal benefits of increased reliability are equated with corresponding marginal costs. The inferior quality of service which plagued MCI in its start-up phase was, at least in part, due to regulatory and technological constraints which precluded efficient interconnection with the Bell System's local distribution network. MCI now makes claim of network reliability superior to that of AT&T.

Elements of the Model

The regulator wishes to maximize a weighted average of consumer surplus across two distinct markets. These markets might represent the local service and long-distance (or carrier access) markets in the telephone industry. Let $\beta \in [0,1]$ and $1-\beta$ denote the regulator's weight on consumer surplus in markets 1 and 2, respectively. These weights enable us to simulate a regulator's interest in certain social policy objectives (i.e., universally available telephone service) that transcend pure efficiency considerations.

There are three players in the game to be analyzed: the regulator, the incumbent (regulated) firm, and the fringe competitor. The incumbent is a franchised monopolist in market 1 in the sense that competition is strictly prohibited. In market 2, the incumbent faces an exogenous fringe competitor. The term "exogenous fringe" means that the regulator can exert only indirect control over the fringe by setting prices or quantities, but retains no other instruments to control the fringe directly. This set-up again reflects the institutional structure of the telecommunications industry, wherein both technological advance and externalities in the design of regulatory policies frequently limit the ability of a regulator to directly control the degree of competitive entry.[9]

The incumbent's profits in market 1 are denoted by $\pi^1 = [p_1\text{-}v\text{-}k]q_1$, where $p_1 = p_1(q_1)$ is the market price, $p_1(q_1)$ is the inverse demand function and q_1 is market (and firm) output. Variable and capital costs per unit of output are denoted by v and k, respectively.

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[9] An example may prove instructive. The Federal Communications Commission (FCC) regulates the electromagnetic spectrum in the United States. In the *Above 890 Decision* (1959), the FCC authorized the construction of private microwave networks in frequencies above 890 megacycles. This decision effectively sanctioned competition in both interstate and intrastate telecommunications markets, but the ratemaking authority for intrastate telecommunications was reserved to the state public service commissions (PSCs). The PSCs could thus indirectly affect the degree of competitive entry through telephone company rate structures, but were otherwise powerless to affect the degree of entry directly. See Weisman (1989b, pp. 341-350).

The incumbent's profits in market 2 are denoted by $\pi^2 = \Big[\{p_2\text{-}v\text{-}k\}\{1\text{-}e\} + \gamma e\{\phi(p_2 - v) - k\}\Big]\, q_2$, where $p_2 = p_2(q_2)$ is the market price, $p_2(q_2)$ is the inverse demand function and q_2 is market output. Let $e(p_2) \in [0,1]$ denote the fringe share of market output with $e'(p_2) > 0$. The incumbent's COLR obligation is denoted by $\gamma \in [0,1]$ so that γe represents the share of fringe output that is backed-up by the incumbent as the COLR. Let $\phi \in [0,1]$ denote the probability that the fringe (network) operation will fail. The variable cost per unit of output for the fringe is denoted by $\tilde{v}$, whereas fringe fixed (capital) costs are denoted by $F(\phi)$, with $F'(\phi) < 0$, $F''(\phi) > 0$, $F(0) = \infty$ and $F(1) = 0$. Consumer welfare is given by $W^c(q_1,q_2) = \beta S^1(q_1) + (1\text{-}\beta)S^2(q_2)$, where $S^i(q_i)$ denotes consumer surplus in market i, i = 1, 2 and

(0) $$S^i(q_i) = \int_0^{q_i} p_i(z_i)dz_i - p_i(q_i)q_i.$$

Finally, we define the own price elasticity of demand in market i by $\varepsilon_i = -(\partial q_i/\partial p_i)(p_i/q_i)$, i = 1,2, and the competitive fringe elasticity by $\varepsilon_c = e'(p_2)(p_2/e)$. We assume throughout the analysis that the fringe output is increasing in p_2, which implies that $\varepsilon_c > \varepsilon_2$.

Lemma 1: If the output of the competitive fringe is strictly increasing in p_2, then $\varepsilon_c > \varepsilon_2$.

Proof: Let the fringe output be given by

(1) $$\tilde{q}_2 = e(p_2)q_2.$$

(2) $$d\tilde{q}_2/dp_2 = e'(p_2)q_2 + e(dq_2/dp_2).$$

Dividing (2) through by e and q_2 and multiplying through by p_2 yields

(3) $$d\tilde{q}_2/dp_2 = e'(p_2)(p_2/e) + (dq_2/dp_2)(p_2/q_2), \text{ so}$$

(3′) $$d\tilde{q}_2/dp_2 = \varepsilon_c - \varepsilon_2 > 0$$

when $\varepsilon_c > \varepsilon_2$. ■

The regulator's problem [RP-1] is to

$$(4)\qquad \underset{\{q_1,q_2,\phi\}}{\text{Maximize}} \qquad W^c(q_1,q_2) = \beta\left[\int_0^{q_1} p_1(z_1)dz_1 - p_1q_1\right] + [1-\beta][1-\phi]\left[\int_0^{q_2} p_2(z_2)dz_2 - p_2q_2\right]$$

$$+ [1-\beta][\phi]\left[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2q_2^*\right],$$

subject to:

(5) $\pi^1 + \pi^2 \geq 0,$

(6) $\phi \in \underset{\phi'}{\text{argmax}}\left[\,[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}\,][q_2] - F(\phi')\,\right],$

(7) $\phi \in [0,1],$

(8) $\gamma \in [0,1]$, and

(9) $q_i \geq 0,\ i = 1,2,$

where $q_2^* = q_2[1 - (1-\gamma)e]$.

In [RP-1], equation (5) is the individual rationality (IR) or participation constraint for the incumbent. Equation (6) defines the fringe's profit-maximizing choice of reliability. Equation (7) defines the feasible bounds for the fringe choice of reliability. Equation (8) defines the feasibility bounds for the incumbent's COLR obligation which is treated exogenously in this problem. Equation (9) rules out negative output quantities. Note that q_2^* represents market 2 output when the fringe operation fails since $(1-\gamma)e$ is the share of fringe output not backed-up by the incumbent as the COLR. Figure 4-1 illustrates consumer surplus in market 2.

Benchmark Solutions

We begin by establishing the benchmark first-best case. The regulator's problem [RP-2] is identical to [RP-1] with the exception that the incentive compatibility constraint (6) representing the fringe choice of reliability is omitted and the COLR obligation (γ) is treated as an endogenous parameter. In this problem, the regulator has perfect commitment ability to specify, q_1, q_2, γ and ϕ. The Lagrangian for [RP-2] is given by

$$(10) \qquad \mathcal{L} = \beta\Big[\int_0^{q_1} p_1(z_1)dz_1 - p_1q_1\Big] + [1-\beta][1-\phi]\Big[\int_0^{q_2} p_2(z_2)dz_2 - p_2q_2\Big]$$

$$+ [1-\beta][\phi]\Big[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2q_2^*\Big] + \lambda\Big[q_1(p_1-v-k) + q_2(p_2-v-k)(1-e)$$

$$+ \gamma e q_2[\phi(p_2-v)-k]\Big] + \delta[1-\phi] + \xi[1-\gamma],$$

where λ, δ and ξ are the Lagrange multipliers associated with (5), (7) and (8), respectively.

In the first proposition, we show how the regulator will optimally set the incumbent's COLR obligation (γ) and the unreliability of the competitive fringe (ϕ).

Proposition 1: At the solution to [RP-2], $\phi = 1$ if and only if $\gamma = 1$ and $\phi = 0$ if and only if $\gamma = 0$.

Proof: Necessary first-order conditions for ϕ and γ include

(11) ϕ: $[1-\beta][S(q_2^*)-S(q_2)] + \lambda q_2\gamma e(p_2-v) - \delta \leq 0$; $\phi[\mathcal{L}_\phi] = 0$,

and

(12) γ: $[1-\beta][\phi][p_2(q_2^*)-p_2(q_2)][eq_2] + \lambda e q_2[\phi(p_2-v)-k] - \xi \leq 0$; $\gamma[\mathcal{L}_\gamma] = 0$.

From (11),

(i) when $\gamma = 1$, $S^2(q_2^*) = S^2(q_2)$, $\delta > 0$ and $\phi = 1$; and

(ii) when $\gamma = 0$, $S^2(q_2^*) < S^2(q_2)$, $\mathcal{L}_\phi < 0$ and $\phi = 0$.

From (12),

(iii) when $\phi = 0$, $p_2(q_2^*) = p_2(q_2)$, $\mathcal{L}_\gamma < 0$ and $\gamma = 0$; and

(iv) when $\phi = 1$, $p_2(q_2^*) > p_2(q_2)$, $\xi > 0$ and $\gamma = 1$. ■

If one hundred percent back-up is in place ($\gamma = 1$), the incumbent serves as the COLR for all of the fringe output, and it is optimal for the regulator to choose a perfectly unreliable fringe. If $\phi < 1$, inefficient duplication of facilities will result. Conversely, if the fringe network is perfectly reliable ($\phi = 0$), then it is optimal to relieve the incumbent of its COLR obligation

and set $\gamma = 0$, since any value of $\gamma > 0$ results in the deployment of capital that will never be utilized.

Now consider optimal pricing rules for q_1 and q_2 assuming $q_i > 0$, $i = 1,2$.

(13) $(p_1\text{-}v\text{-}k)/p_1 = [\lambda - \beta]/\lambda\varepsilon_1$,

and

(14) $$[1-\beta]\Big[1 + \phi\Big[[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau + (\gamma-1)e\Big]\Big] + \lambda\Big[[p_2-v-k][(1-e)\varepsilon_2 + e\varepsilon_c]/p_2$$
$$+ \gamma e[\phi(p_2-v)-k][\varepsilon_2-\varepsilon_c]/p_2 - (1-e) - \gamma\phi e\Big] = 0,$$

where $\tau = [p_2(q_2^*) - p_2(q_2)]/p_2(q_2)$. Equation (14) implicitly defines the optimal pricing rule for market 2. Observe now that when there is no competitive fringe ($e = 0$), (14) reduces to

(15) $(p_2\text{-}v\text{-}k)/p_2 = [\lambda - (1-\beta)]/\lambda\varepsilon_2$.

Dividing (15) into (13) and assuming the regulator weights consumer surplus equally in the two markets so that $\beta = ½$, we obtain

(16) $$\frac{(p_1-v-k)/p_1}{(p_2-v-k)/p_2} = \frac{\varepsilon_2}{\varepsilon_1},$$

which is the standard Ramsey pricing rule. If we now set $\gamma = \phi = 0$ so that we have a perfectly reliable fringe with no COLR obligation, the optimal pricing rule in (14) reduces to

(17) $(p_2^e\text{-}v\text{-}k)/p_2^e = [\lambda(1-e)-(1-\beta)]/\lambda[(1-e)\varepsilon_2+e\varepsilon_c]$.

Since $\varepsilon_c > \varepsilon_2$, the optimal price is lower with a competitive fringe than in the standard Ramsey pricing rule, or $p_2^e < p_2$. The presence of a competitive fringe tends to lower the optimal price in market 2. Stated differently, the price for market 1 must now carry a heavier burden of satisfying the incumbent's revenue requirement, or participation constraint.[10] This occurs because the fringe raises the effective price elasticity for the incumbent in market 2.

[10] This type of argument was a familiar refrain on the part of AT&T when fringe competitors (e.g., MCI and U.S. Sprint) first appeared in the long-distance telephone market. See Wenders (1987) chapter 8 and 9.

Let p_2^c define the optimal price when the incumbent maintains a COLR obligation ($\gamma > 0$). In the next proposition, we characterize the relationship between p_2^c and p_2^e, where the superscripts refer to COLR (c) and competitive entry (e), respectively.

Proposition 2: If $\gamma \geq \max[\frac{1}{2}, (2\varepsilon_2-\varepsilon_c)/(\varepsilon_2-\varepsilon_c)]$, there exists a $\tilde{\phi}$ such that $p_2^c < p_2^e\ \forall\ \phi < \tilde{\phi}$ and

$p_2^c > p_2^e\ \forall\ \phi > \tilde{\phi}$.

Proof: The optimal pricing rule in (14) can be written as

$$(18)\qquad (p_2^c\text{-}v\text{-}k)/p_2^c = \Big[\lambda[(1\text{-}e)+\phi\gamma e]/\lambda\text{-}[1\text{-}\beta]\Big[1+\phi[[\varepsilon_2+(\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1)e]\tau+(\gamma\text{-}1)e]]\Big]/\lambda$$
$$- \gamma e[\phi(p_2\text{-}v)\text{-}k]/p_2\Big]/[(1\text{-}e)\varepsilon_2 + e\varepsilon_c].$$

(i) For $\phi = 0$ (18) reduces to

$$(19)\qquad (p_2^c\text{-}v\text{-}k)/p_2^c = \Big[[\lambda(1\text{-}e) - (1\text{-}\beta)]/\lambda + \gamma ek(\varepsilon_2\text{-}\varepsilon_c)/p_2\Big]/[(1\text{-}e)\varepsilon_2 + e\varepsilon_c] <$$
$$[\lambda(1\text{-}e) - (1\text{-}\beta)]/\lambda[(1\text{-}e)\varepsilon_2 + e\varepsilon_c] = (p_2^e\text{-}v\text{-}k)/p_2^e.$$

(ii) For $\phi = 1$, (18) reduces to

$$(20)\qquad (p_2^c\text{-}v\text{-}k)/p_2^c = \Big[\lambda[(1\text{-}e)+\gamma e]\text{-}[1\text{-}\beta][1+[\varepsilon_2+(\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1)e]\tau+(\gamma\text{-}1)e]\Big]/\lambda\hat{\varepsilon}$$
$$< [\lambda(1\text{-}e) - (1\text{-}\beta)]/\lambda[(1\text{-}e)\varepsilon_2 + e\varepsilon_c] = (p_2^e\text{-}v\text{-}k)/p_2^e,$$

where $\hat{\varepsilon} = [(1\text{-}e)\varepsilon_2 + e\varepsilon_c + \gamma e(\varepsilon_2\text{-}\varepsilon_c)]$, provided that

$$(21)\qquad \lambda\gamma e > [1\text{-}\beta][1+[\varepsilon_2+(\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1)e]\tau + (\gamma\text{-}1)e],$$

or

$$(22)\qquad e > [\varepsilon_2+(\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1)e]\tau,$$

since $\lambda \geq \max[\beta,(1\text{-}\beta)]$. Now recognize that

$$(23)\qquad e > 2\varepsilon_2\tau > [\varepsilon_2+(\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1)e]\tau, \text{ if}$$

$$(24)\qquad \varepsilon_2 > (\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1) > (\varepsilon_2\text{-}\varepsilon_c)(\gamma\text{-}1)e.$$

Solving for γ in (24) yields

$$(25)\qquad \gamma > (2\varepsilon_2\text{-}\varepsilon_c)/(\varepsilon_2\text{-}\varepsilon_c),$$

which is one of the conditions of the proposition. Observe from (23) that

(26) $\quad \varepsilon_2\tau = [q_2 - q_2[1+(\gamma-1)e]]/q_2 = 1 - [1+(\gamma-1)e] = (1-\gamma)e.$

Hence, upon substitution of (26) into (23)

(27) $\quad e > 2(1-\gamma)e.$

Canceling terms and solving for γ in (27) yields

(28) $\quad \gamma > ½,$

which is another condition of the proposition. Equations (25) and (28) jointly require that $\gamma \geq \max\,[½, (2\varepsilon_2-\varepsilon_c)/(\varepsilon_2-\varepsilon_c)]$, which is the statement in the proposition. Since the optimal pricing rule is assumed to be differentiable for $\phi \in [0,1]$, it is also continuous for $\phi \in [0,1]$ and the Intermediate Value Theorem applies. Hence, there exists a $\tilde{\phi} \in [0,1]$ such that $p_2^c = p_2^e$ for $\phi = \tilde{\phi}$. The result follows. ■

For low values of ϕ, the firm realizes a net loss on its default operations since it incurs capital costs but little or no offsetting revenues. Hence, it is optimal to set $p_2^c < p_2^e$ to minimize the fringe output for which the incumbent serves as the (unremunerative) COLR. For high values of ϕ, it is as if there is not a fringe at all (note: for $\phi = 1$, there is essentially no fringe) provided γ is sufficiently large to serve the default output and it is optimal to set $p_2^c > p_2^e$.

The next proposition characterizes the optimal price in market 2 when the fringe is unreliable ($\phi > 0$) and there is no COLR obligation ($\gamma = 0$).

Proposition 3: $p_2^c < p_2^e$ at $\gamma = 0\ \forall\ \phi > 0$.

Proof: With $\gamma = 0$, the optimal price term in (14) can be written as

(29) $\quad (p_2^c\text{-}v\text{-}k)/p_2^c = \Big[\lambda[(1\text{-}e)]/\lambda\text{-}[1\text{-}\beta]\Big[1+\phi[[\varepsilon_2+(\varepsilon_c\text{-}\varepsilon_2)e]\tau\text{-}e]\Big]/\lambda[(1\text{-}e)\varepsilon_2+e\varepsilon_c]$

$$< [\lambda(1\text{-}e) - (1\text{-}\beta)]/\lambda[(1\text{-}e)\varepsilon_2 + e\varepsilon_c] = p_2^e\text{-}v\text{-}k)/p_2^e$$

$\forall\ \phi > 0$, provided that

(30) $[\varepsilon_2 + (\varepsilon_c - \varepsilon_2)e]\tau > e$, and

(31) $[(1-e)\varepsilon_2 + e\varepsilon_c]\tau > e$.

Let $\varepsilon_c = z\varepsilon_2$, where $z > 1$ since $\varepsilon_c > \varepsilon_2$. Substitution into (31) yields

(32) $[(1-e)\varepsilon_2 + ze\varepsilon_2]\tau > e$.

Consolidating terms yields

(33) $[1+e(z-1)]\varepsilon_2\tau > e$.

Observe that $\varepsilon_2\tau = (1-\gamma)e$. Substitution into (33) yields

(34) $[1+e(z-1)][(1-\gamma)e] > e$.

Imposing the $\gamma = 0$ condition of the proposition yields

(35) $[1+e(z-1)]e > e$,

(36) $1+e(z-1) > 1$, and

(37) $e(z-1) > 0$,

which is satisfied $\forall\ e > 0$ since $z > 1$. ■

If $\phi > 0$, there is a nonzero probability that demand lost to the fringe will not be served since $\gamma = 0$. Hence, there is an expected loss of consumer surplus on output supplied by the competitive fringe. The regulator desires to minimize this expected loss in consumer surplus, so he sets a relatively low price in order to retain a larger share of total output with the incumbent.

In fact, the higher the probability of fringe failure, the lower the optimal price set by the regulator. This result is summarized in proposition 4.

Corollary to Proposition 3: $p_2^c < p_2^e$ at $\gamma = 1$ and $\phi = 0$.

Proof: The proof is similar in technique to that for proposition 3 and is therefore omitted. ■

With a one hundred percent COLR obligation and a zero probability of fringe failure, the optimal price is lowered to reduce unremunerative capital costs. The lower price ensures that a larger share of output remains with the incumbent since $e'(p_2) > 0$.

We now examine the general comparative statics for [RP-2], treating ϕ and γ as exogenous parameters. Let $\bar{H}$ denote the bordered Hessian for [RP-2] and $|\bar{H}|$ its corresponding determinant. Necessary second-order conditions which are assumed to hold require that $|\bar{H}| > 0$ at a maximum. We begin by identifying the sign pattern for $\bar{H}$ and its corresponding parameter vector for the limiting values of ϕ and γ.

Total differentiation of the necessary first-order conditions for [RP-2] with respect to ϕ yields the following sign pattern for $\bar{H}$ and the corresponding parameter vector.

$$(38) \qquad \bar{H}\,|_{\gamma=1} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 \\ + \\ - \end{bmatrix}.$$

$$(39) \qquad \bar{H}\,|_{\gamma=0} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 0 \\ - \\ 0 \end{bmatrix}.$$

Application of Cramer's rule yields standard comparative static results which we formalize in the following proposition.

Proposition 4: At the solution to [RP-2],

(i) if $\gamma = 1$, $dp_1/d\phi < 0$ and $dp_2/d\phi > 0$ for ε_1 small; and

(ii) if $\gamma = 0$, $dp_1/d\phi > 0$ and $dp_2/d\phi < 0$.

An increase in the rate of fringe failure with $\gamma = 1$ implies an increase in default output revenues with which to offset COLR capital costs. Since $\lambda > 0$ at the solution to [RP-2], the increase in revenues allows p_1 to fall. Hence, the more unreliable the competitive fringe, the lower the price in market 1.

At $\gamma = 1$, p_2 decreases with the price elasticity of demand in market 2 for ε_1 sufficiently small. The more reliable the fringe, the higher the effective price elasticity for the incumbent

since a smaller share of output diverted to the fringe returns to the incumbent in the form of default output.

With no COLR obligation ($\gamma = 0$), an increase in the unreliability of the fringe will cause the regulator to reduce the price for p_2 in order to retain a greater amount of output with the incumbent (see proposition 3). To ensure the incumbent firm remains viable, with a binding IR constraint ($\lambda > 0$), a reduction in p_2 requires an increase in p_1.

Total differentiation of the necessary first-order conditions for [RP-2] with respect to γ yields the following sign pattern for $\bar{H}$ and the corresponding parameter vector.

(40) $$\bar{H}\,|_{\phi=1} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \text{ and } \begin{bmatrix} 0 \\ + \\ - \end{bmatrix}.$$

(41) $$\bar{H}\,|_{\phi=0} = \begin{bmatrix} - & 0 & - \\ 0 & - & - \\ - & - & 0 \end{bmatrix} \text{ and } \begin{bmatrix} 0 \\ - \\ + \end{bmatrix}.$$

Application of Cramer's rule again yields a set of standard comparative static results which we formalize in the following proposition.

Proposition 5: At the solution to [RP-2],

(i) at $\phi = 1$, $dp_1/d\gamma < 0$; and

(ii) at $\phi = 0$, $dp_1/d\gamma > 0$.

With a one hundred percent default rate ($\phi = 1$), deploying capital costs to serve as the COLR is financially remunerative for the firm since p_2 is optimally set above marginal cost and p_1 falls. The effect on p_2 is ambiguous. An increase in p_2 results in output moving to the fringe (independent of whether it is ultimately served) which may prove to be financially unremunerative

for the incumbent. This occurs because raising p_2 may divert more traffic to the fringe than the incumbent can serve on a default basis for any given level of γ.

With a perfectly reliable fringe ($\phi = 0$), raising γ increases the level of financially unremunerative capital costs which are financed by raising p_1. The effect on p_2 is again ambiguous. Even though costs rise with an increase in γ, the presence of the fringe renders it uncertain as to whether p_2 will be increased to finance these additional capital costs.

Principal Findings

We now examine the properties of the general model [RP-1]. In this modeling framework, the competitive fringe chooses its optimal level of reliability. The regulator is the Stackelberg leader, choosing q_1, q_2 and γ. The competitive fringe is the Stackelberg follower, choosing ϕ. Recognize that the timing in [RP-1] is such that the regulator is able to affect the fringe reliability choice (ϕ) only indirectly, as it is assumed that the regulator has (perfect) knowledge of the fringe reaction function. In subsequent analysis, [RP-3], we reverse the timing and allow the fringe to be the Stackelberg leader.

We begin with analysis of the reliability choice of the fringe which appears as an incentive compatibility constraint (6) in [RP-1]. This constraint is expressed as follows.

$$(42) \qquad \phi \in \underset{\phi'}{\text{argmax}} \left[[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}][q_2] - F(\phi')\right].$$

For an interior solution, (42) requires

$$(43) \qquad -eq_2(p_2 - \tilde{v}) - F'(\phi) = 0.$$

If $0 < (p_2 - \tilde{v}) < \infty$, we obtain an interior solution for ϕ since $F(0) = \infty$. Sufficient second-order conditions (concavity) for a unique maximum (ϕ^*) requires that

$$(44) \qquad -F''(\phi) < 0.$$

which is satisfied since $F''(\phi) > 0$. Equation (43) can be viewed as the competitive fringe reaction function for ϕ conditioned on the regulator's choice of p_2 or q_2. Hence, for the regulator's choice of p_2 or q_2, the reaction function yields a unique ϕ^*.

Differentiating the reaction function in (43) implicitly with respect to p_2, we obtain

(45) $$-e'q_2(p_2 - \tilde{v}) - e(\partial q_2/\partial p_2)(p_2 - \tilde{v}) - eq_2 - F''(\phi)(d\phi/dp_2) = 0.$$

Rearranging terms and appealing to the definition of $\boldsymbol{\varepsilon}_2$ and $\boldsymbol{\varepsilon}_c$, we obtain

(46) $$-\boldsymbol{\varepsilon}_c(p_2 - \tilde{v})/p_2 + \boldsymbol{\varepsilon}_2(p_2 - \tilde{v})/p_2 - 1 - F''(\phi)/eq_2(d\phi/dp_2) = 0.$$

Rearranging terms and solving for $d\phi/dp_2$ yields

(47) $$d\phi/dp_2 = [eq_2/F''(\phi)]\Big[[(p_2 - \tilde{v})(\boldsymbol{\varepsilon}_2 - \boldsymbol{\varepsilon}_c)]/p_2 - 1\Big] < 0.$$

The inequality in (47) holds because $\boldsymbol{\varepsilon}_c > \boldsymbol{\varepsilon}_2$. Hence, the higher the price (p_2) set by the regulator, the more reliable the competitive fringe operation. When p_2 rises, the fringe can serve a larger share of traffic at a higher price. It thus has incentives to increase reliability with a higher p_2. Note also that $d\phi/dq_2 > 0$ since $p_2 = p_2(q_2)$ and $\partial p_2/\partial q_2 < 0$.

The Lagrangian for [RP-1] is given by

(48) $$\mathcal{L} = \beta\Big[\int_0^{q_1} p_1(z_1)dz_1 - p_1q_1\Big] + [1-\beta][1-\phi]\Big[\int_0^{q_2} p_2(z_2)dz_2 - p_2q_2\Big]$$
$$+ [1-\beta][\phi]\Big[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2q_2^*\Big] + \lambda\Big[q_1(p_1-v-k) + q_2(p_2-v-k)(1-e)$$
$$+ \gamma eq_2[\phi(p_2-v)-k]\Big] + \rho[-eq_2(p_2-\tilde{v}) - F'(\phi)] + \delta[1-\phi] + \xi[1-\gamma].$$

Necessary first-order conditions for q_2, assuming an interior solution and rearranging terms yields

(49) $$[1-\beta]\Big[1 + \boldsymbol{\varepsilon}_2(\partial\phi/\partial q_2)[S(q_2^*) - S(q_2)] + \phi[\boldsymbol{\varepsilon}_2 + (\boldsymbol{\varepsilon}_2-\boldsymbol{\varepsilon}_c)(\gamma-1)e]\tau + (\gamma-1)e\Big] +$$
$$\lambda\Big[[p_2-v-k][(1-e)\boldsymbol{\varepsilon}_2 + e\boldsymbol{\varepsilon}_c]/p_2 + \gamma e[\phi(p_2-v)-k][\boldsymbol{\varepsilon}_2-\boldsymbol{\varepsilon}_c]/p_2 - (1-e) - \phi\gamma e +$$
$$\gamma\boldsymbol{\varepsilon}_2 q_2 e(\partial\phi/\partial q_2)(p_2-v)/p_2\Big] + \rho\Big[e(p_2-\tilde{v})(\boldsymbol{\varepsilon}_2-\boldsymbol{\varepsilon}_c)/p_2 + e - F''(\phi)(\partial\phi/\partial q_2)\boldsymbol{\varepsilon}_2/p_2\Big] = 0.$$

Equation (49) implicitly defines the optimal pricing rule for p_2 in [RP-1]. Denote this optimal price by $\tilde{p}_2^c$. We define the following terms

(50) $b_1 = \gamma\varepsilon_2 q_2 e(p_2-v)/p_2 > 0$, and

(51) $b_2 = \rho\left[e(p_2-\tilde{v})(\varepsilon_2-\varepsilon_c)/p_2+e - F''(\phi)(\partial\phi/\partial q_2)\varepsilon_2/p_2\right] > 0.$

In the next proposition, we characterize the relationship between $\tilde{p}_2^c$ and p_2^c. Since the regulator cannot specify ϕ directly in [RP-1], he indirectly influences ϕ through his choice of $\tilde{p}_2^c$.

Proposition 6: At the solution to [RP-1], $\tilde{p}_2^c < p_2^c$ when $\gamma = 1$.

Proof: With $\gamma = 1$, $S^2(q_2^*) = S^2(q_2)$. The optimal pricing rule in (49) can thus be written as

(52) $$(\tilde{p}_2^c - v - k)/\tilde{p}_2^c = \Big[\lambda[(1-e) + \phi\gamma e - b_1 - (b_2/\lambda)] - [1-\beta]\Big[1 + \phi(\gamma-1)e + \phi[\varepsilon_2 + (\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau\Big] - \gamma e\lambda[\phi(p_2-v)-k][\varepsilon_2-\varepsilon_c]/p_2\Big]/\lambda[(1-e)\varepsilon_2 + e\varepsilon_c]$$

$$< \Big[\lambda[(1-e)+\phi\gamma e/\lambda-[1-\beta]\Big[1+\phi\{[\varepsilon_2+(\varepsilon_2-\varepsilon_c)(\gamma-1)e]\tau+(\gamma-1)e\}\Big]/\lambda - \gamma e[\phi(p_2-v)-k]/p_2\Big]/[(1-e)\varepsilon_2 + e\varepsilon_c] = (p_2^c - v - k)/p_2^c,$$

since $b_1 > 0$ and $b_2 > 0$. ■

With one hundred percent back-up ($\gamma = 1$), the regulator wants an entirely unreliable fringe ($\phi = 1$) in order to avoid inefficient duplication of facilities (unremunerative capital costs). Yet in [RP–1], the regulator cannot control ϕ directly, only indirectly through p_2. From the competitive fringe reaction function, $d\phi/dq_2 > 0$. Hence, in order to induce the fringe to choose a lower level of reliability (higher ϕ), the regulator lowers p_2 relative to [RP-1]. It follows that $\tilde{p}_2^c < p_2^c$.

The optimal price is lower when the fringe chooses its own level of reliability in order to maximize profits under a one hundred percent COLR obligation. The effect of this lower price is not only to ensure that a larger share of traffic remains with the incumbent since $e'(p_2) > 0$, but also to induce more default output since $d\phi/dp_2 < 0$.

In [RP-1], we assume that the regulator is the Stackelberg leader and the competitive fringe is the Stackelberg follower. In [RP-3], we reverse the timing to explore the implications of allowing the competitive fringe to lead with its choice of reliability (ϕ).[11]

In [RP-3], the regulator's problem is to

$$\text{(53)} \quad \underset{\{q_1, q_2, \phi\}}{\text{Maximize}} \left[[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}][q_2] - F(\phi')\right],$$

subject to:

$$\text{(54)} \quad q_1, q_2 \in \underset{q_1', q_2'}{\text{argmax}}\ \beta\left[\int_0^{q_1'} p_1(z_1)dz_1 - p_1 q_1'\right] + [1-\beta][1-\phi]\left[\int_0^{q_2'} p_2(z_2)dz_2 - p_2 q_2'\right]$$

$$+ [1-\beta][\phi]\left[\int_0^{q_2^*} p_2(z_2)dz_2 - p_2 q_2^*\right],$$

subject to:

$$\text{(55)} \quad \pi^1 + \pi^2 \geq 0,$$

$$\text{(56)} \quad \phi \in [0,1],$$

$$\text{(57)} \quad \gamma = \bar{\gamma}, \text{ and}$$

$$\text{(58)} \quad q_i \geq 0,\ i = 1,2,$$

where $q_2^* = q_2[1 - (1-\gamma)e]$.

With the exception of the timing reversal, the structure of [RP-3] is quite similar to [RP–1]. One exception is equation (57) which specifies a constant COLR obligation for the incumbent firm. As a practical matter, the COLR obligation is not a topic for standard tariff review. In fact, in a number of state jurisdictions, the COLR obligation is a provision of state statute and thus not amenable to review and modification by public utility regulators. Given that

[11] The timing sequence in [RP-3] is modeled after the FCC's practice of allowing incumbent firms to respond to new service offerings of competitors. The set of rules that the FCC enforces with regard to the incumbent's ability to respond is referred to formally as the Competitive Necessity Test.

one of our primary objectives here is to explain competitive fringe strategy in response to existing regulatory institutions, this modeling convention appears within reason.

We begin our analysis of [RP-3] by examining the objective function of the competitive fringe. Let π^f denote the profit function of the competitive fringe, where

(59) $$\pi^f = \Big[[1-\phi'][e(p_2)][p_2(q_2)-\tilde{v}][q_2] - F(\phi')\Big].$$

Differentiating (59) with respect to ϕ, assuming an interior solution, we obtain

(60) $$\partial\pi^f/d\phi = -e[p_2(q_2) - \tilde{v}] - F'(\phi) = 0.$$

The first term to the right of the equals sign in (60) can be interpreted as the marginal benefit of increased unreliability; the second term to the right of the equals sign can be interpreted as the marginal cost of increased unreliability. Observe now that if

(61) $$-e[p_2(q_2) - \tilde{v}] - F'(\phi) > (<)\ 0,$$

at the solution to [RP-3], overcapitalization (undercapitalization) in the provision of reliability occurs relative to the benchmark case. To see this, recall that $F''(\phi) > 0$. Hence, if (61) is strictly positive (negative), ϕ is too low (too high) in comparison with the benchmark case. Because a higher degree of reliability is associated with a larger capital expenditure, $F'(\phi) < 0$, it is instructive to refer to this as an overcapitalization (undercapitalization) distortion.

In the next proposition, we characterize sufficient conditions for the overcapitalization (undercapitalization) distortion.

Proposition 7: The competitive fringe overcapitalizes in the provision of reliability at the solution to [RP-3] if $\gamma = 0$ and undercapitalizes if $\gamma = 1$ and ε_1 is small.

Proof: Differentiating (59) with respect to ϕ, assuming an interior solution, and rearranging terms, we obtain

(62) $$-e[p_2(q_2) - \tilde{v}] - F'(\phi) = -[1-\phi'][e'(\partial p_2/\partial q_2)(\partial q_2/\partial\phi)][p_2 - \tilde{v}]q_2$$

$$- [1-\phi'][e][(\partial p_2/\partial q_2)(\partial q_2/\partial\phi)]q_2 - [1-\phi'][e][p_2 - \tilde{v}][\partial p_2/\partial q_2].$$

By proposition 4 part (ii), $\partial q_2/\partial\phi > 0$ at $\gamma = 0$. Hence, for $\gamma = 0$, the expression to the left of the equals sign in the first line of (62) is strictly positive when

(63) $-[1-\phi'][e][(\partial p_2/\partial q_2)(\partial q_2/\partial\phi)]q_2 - [1-\phi'][e][p_2 - \tilde{v}][\partial p_2/\partial q_2] > 0.$

After canceling terms and rearranging, we obtain

(64) $-(\partial p_2/\partial q_2)q_2 - [p_2 - \tilde{v}] > 0$, or

(65) $1 - \varepsilon_2[p_2 - \tilde{v}]/p_2 > 0,$

which is satisfied for $\varepsilon_2 < 1$ (inelastic demand). The second part of the proof follows from proposition 4 part (i). ■

When $\gamma = 0$, an increase in reliability allows p_2 to rise as the regulator is less concerned about retaining output with the incumbent since there is a reduced probability of a fringe failure. The fringe views this increase in price as a de facto subsidy to investment in reliability which leads to the overcapitalization distortion.

When $\gamma = 1$, an increase in reliability decreases the (expected) level of default output for the incumbent since the probability of a fringe failure is reduced.[12] The effective price elasticity for the incumbent in market 2 increases with fringe reliability. The optimal price in market 2 is thus reduced to reflect this higher price elasticity.[13] The fringe views this decrease in price as a tax on investment in reliability which leads to the undercapitalization distortion.

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[12] It is conceivable that the fringe may increase reliability so as to strand the incumbent's plant and thereby raise its rivals' costs along the lines suggested by Salop and Scheffman (1983). This is advantageous for the fringe, however, only when the incumbent finances the revenue deficiency by raising the price in market 2. Yet, raising the price in market 2 will not only divert more traffic to the fringe, but it will also induce the fringe to increase reliability resulting in an even larger revenue deficiency for the incumbent.

[13] The price elasticity of demand for basic local telephone service is very small, on the order of 0.10 or less in absolute value. See Taylor (1993). This corresponds to the condition in the proposition that ε_1 be small.

Proposition 7 thus supports Kahn's (1971) original hypothesis that fringe competitors may tend to underinvest in reliability. He argues that consumers may be reluctant to patronize the competitive fringe unless the incumbent serves as the COLR due to concerns about service reliability.[14] We find that for a sufficiently high COLR obligation ($\gamma = 1$), the fringe has incentives to underinvest in reliability. Conversely, for a sufficiently low COLR obligation ($\gamma = 0$), the fringe has incentives to overinvest in reliability. In essence, (COLR) supply creates its own demand in that consumer concerns about fringe reliability may be validated as self-fulfilling prophecies in equilibrium.

The implications of proposition 7 for competitor strategy in the telecommunications industry raise interesting questions for further research. For example, MCI and U.S. Sprint now compete with AT&T amid claims of superior reliability. It would be interesting to examine whether these competitors have overcapitalized in the provision of reliability, and whether such overcapitalization can be explained by a relaxation of AT&T's COLR obligation.

Similar developments are unfolding in the carrier access market where entrants are deploying fiber optic networks with reliability standards (arguably) superior to those of common carriers.[15] Absent demand and cost information, it is not possible to determine whether these activities represent overcapitalization in the provision of reliability. Yet, our findings do suggest the manner in which the incumbent's COLR obligation (γ) will affect the fringe competitors' choice of reliability.

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[14] This suggests that $e = e(p_2,\phi,\gamma)$, with $e_1 > 0$, $e_2 < 0$ and $e_3 > 0$, where the subscripts denote partial derivatives. Kahn suggests that concerns about service reliability are alleviated when the incumbent serves as the COLR for the entire market, so $e_2(p_2,\phi,1) = 0$. This is supported by the case study in Weisman (1989c). Hence, when $\gamma = 1$, the fringe share function can reasonably be expressed solely as a function of p_2, which is the formulation here. Incorporating the more general formulation of the fringe share function into the analysis is a topic for future research.

[15] See Weisman (1989b, 1989c) and Metropolitan Fiber Systems (1989).

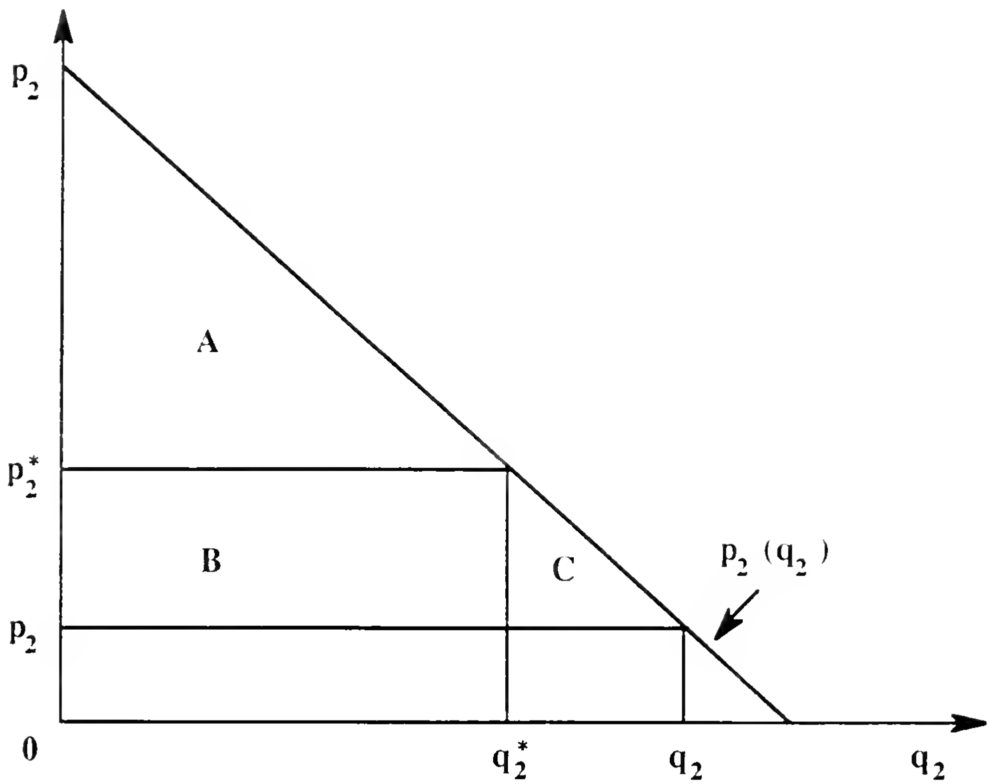
Conclusion

The advent of competition for public utility-like services poses complex problems for regulators who must ultimately balance equity and efficiency considerations in crafting public policy. Frequently, this dichotomy results in asymmetric regulation wherein the incumbent bears responsibility for certain historical obligations not likewise borne by its competitors. Here, we have focused on one such obligation, the responsibility of the incumbent to serve as the nondiscriminatory COLR.

In general, we find that in the presence of a relatively reliable fringe competitor ($\phi < \tilde{\phi}$), the optimal price (p_2^c) is lower when the incumbent is required to serve as the COLR. Moreover, when the fringe is allowed to choose its level of reliability strategically while the incumbent must maintain a one hundred percent COLR obligation ($\gamma = 1$), the optimal price ($\tilde{p}_2^c$) is lower yet, $\tilde{p}_2^c < p_2^c$.

Our principal finding reveals that the competitive fringe has incentives to overcapitalize (undercapitalize) in the provision of reliability when the COLR obligation is sufficiently low (high). Here, (COLR) supply creates its own demand in that the need for a COLR becomes a self-fulfilling prophecy in equilibrium. These findings may explain competitive fringe strategies in the telecommunications industry.

As competition intensifies for public utility-like services, regulators may be forced to consider a richer set of policy instruments to address the distortions inherent in a nondiscriminatory COLR obligation. The insightful work of Panzar and Sibley (1978) offers some interesting possibilities in this regard. Here, working within the confines of existing regulatory institutions, we provide some guidance in the design of welfare-enhancing public policies under asymmetric regulation.



$S^2(q_2) = A + B + C$ with probability $1-\phi$

$S^2(q_2^*) = A + B$ with probability ϕ

where $q_2^* = q_2[1-(1-\gamma)e]$.

Figure 4-1: Consumer Surplus in Market 2.

CHAPTER 5
CONCLUDING COMMENTS

This dissertation is composed of three essays on the economics of regulation. In each essay, we began with a given theoretical model and methodically built institutional realism into the underlying mathematical structure. This modeling approach enables us to traverse the expanse between theory and practice while revealing the value of doing so. The results of the analysis cause us to question, and in a number of cases reverse, some important findings in the literature. These results should prove useful to researchers and policymakers in regulated industries. We conclude with a statement of the principal findings from each essay and a brief discussion of prospective topics for future research.

In *Superior Regulatory Regimes In Theory and Practice*, we discovered that while PC regulation is superior to CB regulation, it is not generally true that a hybrid application of PC and CB regulation, what we referred to as MPC regulation, is superior to CB regulation. This is an important result for both theory and policy, as MPC regulation is the dominant form of PC regulation in practice. While regulators were encouraged to adopt PC regulation in order to eliminate a myriad of economic distortions that prevail under CB regulation, MPC regulation may serve only to exacerbate these distortions.

In terms of future research, the analysis reveals that CB regulation can dominate MPC regulation, but the conditions under which this result holds require further analysis, perhaps along the lines suggested by Schmalensee (1989). Our findings also question the superiority of PC

regulation when the firm believes there is a nonzero probability that the regulator will recontract. A rigorous treatment of recontracting-induced distortions is a promising area for future research.

In *Why Less May Be More Under Price-Cap Regulation*, we proved that the firm's dominant strategy is to adopt a form of PC regulation that entails sharing profits with consumers. Profit-sharing provides the regulator with a vested interest in the firm's financial well-being. As a result, the regulator may be induced to choose a lesser degree of competitive entry or a higher price under sharing than if the firm retains its profits in full. The irony here is that the firm may object to sharing on grounds that it subverts economic efficiency, a result consistent with our analysis, only to discover that sharing leads to a higher absolute level of profits.

In this essay, we have demonstrated that profit-sharing is a dominant strategy for the firm under PC regulation, but the task remains to characterize the optimal sharing rule. Moreover, we should attempt to resolve the paradox of why, in practice, regulators prefer sharing and the firm prefers pure price-caps when our results suggest that the opposite should be true.

In *Designing Carrier of Last Resort Obligations*, we derived optimal pricing policies in an environment where the incumbent faces a competitive fringe and is constrained by an asymmetric COLR obligation. We found that the presence of the fringe tends to reduce the optimal price set by the regulator. When the incumbent bears a nonzero COLR obligation and the fringe is relatively reliable, the optimal price is further reduced. The optimal price is lower yet when the fringe is allowed to choose its level of reliability strategically. Our principal finding reveals that the fringe has incentives to overcapitalize (undercapitalize) in the provision of reliability when the incumbent's COLR obligation is sufficiently low (high). Here, (COLR) supply creates its own demand in the sense that the need for a COLR may be validated as a self-fulfilling prophecy in equilibrium.

In terms of future research, it remains to be shown that introducing self-rationing, two-part tariffs along the lines suggested by Panzar and Sibley (1978) and Weisman (1988) will efficiently address this overcapitalization (undercapitalization) distortion. A number of other interesting research topics suggest themselves, such as introducing an endogenous fringe, allowing the firm to charge differently for default output and an analysis of the welfare effects of substituting a COLR constraint for a price-cap constraint when the regulator has imperfect information about the firm's costs.

APPENDIX
CORE WASTE EXAMPLE

Suppose the firm believes the recontracting probability is given by $\phi(\pi_1) = [\exp\{.0007\pi_1\}-1]$, where $\pi_1 \in [0,1000]$. This function satisfies the requisite properties since $\phi(0) = 0$ and $\phi(1000) = 1$. Also, $\phi'(\pi_1) = .0007 \exp\{.0007\pi_1\} > 0$ and $\phi''(\pi_1) = (.0007)^2 \exp\{.0007\pi_1\} > 0$ so that the recontracting probability function is convex. As shown in Table A, the firm has no incentive to engage in waste at lower core market profit levels, but it does at higher core market profit levels. The recontracting elasticity (ε_ϕ) is increasing with π_1 and the relative shares term $(1-\phi\bar{T})/\phi\bar{T}$ is decreasing with π_1. Eventually, a point is reached where the gain in expected profit from reducing the probability of recontracting dominates the loss in direct profits of $(1-\phi\bar{T})$. At profit levels in excess of this critical point, the firm has incentives to engage in pure waste.

TABLE A: Waste is Profitable for the Firm

π_1	$E[\pi_1]$	ϕ	$\bar{T}$	ε_ϕ		$(1-\phi\bar{T})/\phi\bar{T}$	$u_1 > 0$
100	96.4	0.073	0.5	1.028	<	26.397	no
300	264.9	0.234	0.5	1.110	<	7.547	no
700	478.8	0.632	0.5	1.266	<	2.165	no
882.3	505.1	0.855	0.5	1.341	=	1.341	--
950	501.1	0.945	0.5	1.369	>	1.116	yes

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BIOGRAPHICAL SKETCH

Dennis Weisman has accepted the position of assistant professor of economics at Kansas State University. He is currently director-strategic marketing for Southwestern Bell Corporation and an affiliated research fellow with the Public Utility Research Center at the University of Florida. Mr. Weisman has more than ten years experience in the telecommunications industry in the areas of regulation and business strategy development. He has testified in a number of state rate proceedings on bypass and competition in the telecommunications industry, and has written extensively on the economics of regulation with particular emphasis on the telecommunications industry. His work has appeared in numerous professional economic, business and law journals, including the *Yale Journal on Regulation*, *The International Journal of Forecasting*, *Energy Economics*, *Research in Law and Economics*, *The Federal Communications Law Journal* and the *Journal of Cost Management*. His current research interests include superior regulatory regimes in theory and practice, the welfare implications of asymmetric regulation and costing principles for efficient business decisions. Mr. Weisman holds a B.A. in mathematics and economics (magna cum laude in economics) and an M.A. in economics, both from the University of Colorado. Mr. Weisman is a Ph.D. candidate in the Department of Economics at the University of Florida, where he expects his degree to be conferred in May of 1993.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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